

Risk-based Closure Guide

Office of Land Quality
Indiana Department of Environmental Management

Disclaimer

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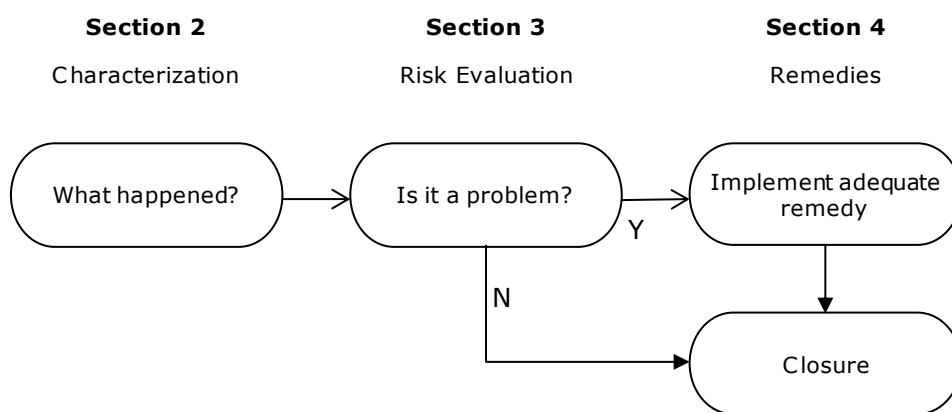
1: Introduction

The Risk-based Closure Guide (R2¹) exists to facilitate consistent application of Indiana Code (IC) [IC 13-12-3-2](#) and [IC 13-25-5-8.5](#), which together form the statutory basis for implementation of risk-based closure in Indiana. The R2 sets forth a framework for characterizing releases, evaluating resulting risk and, when necessary, selecting and implementing appropriate remedies that allow closure.

The R2 follows an outline (Figure 1-A) with three major sections that address, in turn, characterization, risk evaluation, and remedy selection and implementation. Content within these major sections is arranged into a total of nine² broadly defined tasks necessary to comply with statutory requirements for risk-based closure. Each task is defined, justified via legal citation and scientific basis, and illustrated with one or more examples of approaches that the Indiana Department of Environmental Management (IDEM) has determined to be acceptable.

Except where required by statute or rule, the emphasis throughout the R2 is on achieving ends – adequate characterization, an appropriate evaluation of risk and, where necessary, control of risk through selection and implementation of a remedy – rather than dictating specific procedures for doing those things. IDEM recognizes that there are many possible ways to investigate releases and evaluate and control risk, and that approaches different than those described herein may be just as or more appropriate in some situations. Responsible parties are free to propose methods that do not appear in the R2, and IDEM will evaluate proposals to use alternate approaches on their merits.

Figure 1-A: R2 Outline



IDEM will correct, update, or revise the R2 as necessary. Substantive changes to the R2 will go through the nonrule policy document process. Updates will appear on IDEM's [Technical Guidance for Cleanups](#) web page. In addition, IDEM staff can provide clarification regarding updates to, or specific contents of, this volume.

¹ The *Risk-based Closure Guide (R2)* supersedes IDEM's 2012 *Remediation Closure Guide (RCG)*.

² Seven when a remedy proves unnecessary.

1.1 Applicability

Per [IC 13-12-3-2](#), the *R2* applies to the following IDEM remediation programs:

- Petroleum Remediation Section
- Voluntary Remediation Program (VRP)
- Resource Conservation and Recovery Act (RCRA) Subtitle C Programs, including RCRA Treatment Storage and Disposal (TSD) facility closures (where such closures are not otherwise governed by statute and/or rule), and RCRA Corrective Action projects.
- State Cleanup Program (SCP)
- Indiana Brownfields Program (IBP)

Except as provided above, responses to releases completed under these programs may use risk-based remediation objectives established by [IC 13-25-5-8.5](#).

As a non-rule policy, the *R2* is guidance that helps explain IDEM's expectations, but does not have the effect of law. If a conflict exists between the *R2* and state or federal rules and statutes, the rules and statutes will prevail.

Some conditions require quick response action to mitigate any potential imminent and substantial threat to human health or the environment. Examples include:

- Acute exposures to release-related chemicals
- Presence of corrosive, explosive, flammable, or toxic vapors
- Actual or imminent threat to a drinking water supply when the threat is regulated by IDEM under Title 13

The *R2* does not specifically address emergency situations. However, where appropriate, *R2* activities may proceed concurrently with emergency response measures.

1.2 Types of Closure

Closure is IDEM's written recognition that a party has demonstrated attainment of remediation objectives for a release³. Closure approval depends on an adequate characterization of the release and potential receptors that allows informed decisions about the necessity, selection, implementation, and effectiveness of remedies for the release. Closure requires meeting remediation objectives for each release-related chemical in all affected media.

There are two fundamental types of closure:

Unconditional closure means an ongoing remedy is not required at a property. For example, if release-related chemical concentrations at a property are below unconditional remediation objectives (e.g., IDEM's residential published levels), that property is suitable for unrestricted use and would be eligible for unconditional closure. IDEM does not anticipate requiring any additional action at a property that closes unconditionally.⁴

Conditional closure means an ongoing remedy is necessary to reduce exposure risk to an acceptable level. Examples of controls which might prove effective in reducing exposures include physical barriers, such as engineered caps or slurry walls, active remediation systems such as subslab depressurization systems for controlling vapor intrusion, or land use controls, such as residential use prohibitions or groundwater extraction and use restrictions. Releases may need more than one remedy to adequately control risk. Whether a remedy fulfills its purpose will depend on factors like the characteristics of the release-related chemicals and affected media, the means by which those chemicals may move from source to potential receptors, and the nature of the potential receptors.

Unless acceptable lines of evidence show otherwise, adequately controlling risk requires that exposure controls remain in place for as long as release-related chemicals remain at levels exceeding unconditional remediation objectives. For persistent chemicals, this means that controls will need to remain in place for a long time, perhaps even in perpetuity. Though not always necessary, removal or treatment of release-related chemicals will usually reduce the number, scale, and/or duration of ongoing risk-reducing activities or restrictions associated with conditional closure.

Closure always requires a demonstration that release-related chemical concentrations, taking controls into account, do not pose unacceptable risks to human health or the environment, both at closure and over the likely lifetime of the chemicals in the environment. Responsible parties will need to weigh the short-term advantages of conditional closure against the potential costs of maintaining remedies for as long as necessary to address unacceptable risk.

³ Under RCRA, the term closure refers to a series of formal procedures required to minimize the need for maintenance and control, minimize or eliminate post-closure releases of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the environment.

⁴ New information about the presence of release-related chemicals at a property may require post-closure responses, and IDEM may require further action where the conditions that formed the basis for IDEM's approval have changed, not been met, or where scientific advances provide new knowledge regarding a threat to human health that was not previously considered.

1.3 Process Overview

The generalized closure process begins when IDEM learns of a release that requires characterization and continues through risk evaluation and, where necessary, remedy selection and implementation. Some of the tasks described below do not necessarily need to occur in the order listed. For example, it may prove necessary or useful to implement an interim remedy prior to complete characterization. Refer to the sections in parentheses for additional guidance on these tasks.

Characterization Tasks (Section 2)

Task 1 (Section 2.1): *Identify release source(s)*. Determine the type of activity or facility associated with the release and, to the extent possible, the physical location of the source point or source area.

Task 2 (Section 2.2): *Identify and quantify release-related chemical(s)*. Develop and implement appropriate data quality objectives (DQOs) and determine the chemicals and breakdown products likely associated with the release and their concentrations in affected media.

Task 3 (Section 2.3): *Determine the extents of release-related chemical(s)*. Determine the present horizontal and vertical extents of release-related chemicals, against media-specific unconditional remediation objectives. Estimate likely future extents against the same objectives.

Risk Evaluation Tasks (Section 3)

Task 4 (Section 3.1): *Specify decision unit(s) and their use(s)*. Specify the extents and likely future uses of locations where remedy decisions are necessary.

Task 5 (Section 3.2): *Determine representative concentrations*. Develop estimates of release-related chemical concentrations within each decision unit.

Task 6 (Section 3.3): *Specify remediation objectives*. Specify risk-based concentrations or risk levels suitable for unrestricted use or, where risk controls are in place or contemplated, suitable for use considering those controls.

Task 7 (Section 3.4): *Determine whether a remedy is necessary*. Determine whether one or more representative concentrations in decision units exceed unconditional remediation objectives and take applicable lines of evidence into account when deciding whether a remedy is necessary.

Remedy Selection and Implementation Tasks (Section 4)

Task 8 (Section 4.1): *Select a remedy that is likely to be adequate*. Choose a remedy that is likely to adequately control risk, taking into account the present and likely future extents of release-related chemicals, their concentrations, their overlap with potential receptors, land-use specific remediation objectives, and proposed controls, if any.

Task 9 (Section 4.2): *Implement a remedy and show that it is adequate*. Implement the proposed remedy and demonstrate, using sampling data and other means as appropriate, that it adequately controls risk, that it is likely to do so for as long as release-related chemicals are present at concentrations above remediation objectives suitable for residential use, assure compliance with restricted activities, and that future obligations related to ongoing operation and maintenance of the remedy are adequately specified, memorialized, and adequately financially supported.

2: Characterization

For purposes of this document, **characterization** is a determination of the source, nature, and extents of release-related chemicals. [IC 13-25-5-8.5\(c\)](#) requires adequate characterization as a prerequisite to determining whether action is necessary to protect human health and the environment.

Characterization must be sufficient to allow evaluation of the risks, if any, posed by release-related chemicals. The level of effort necessary to adequately characterize a release may vary considerably. In some cases, limited sampling may qualify releases for closure without further investigation. Other releases may require complex multi-stage investigations that span several media. It is rarely possible to know in advance how much work will be necessary to support an adequate evaluation of risk. Any investigation may reveal the need for further investigation.

Information obtained during characterization activities may show that certain actions to protect human health and the environment are necessary, *even before characterization is complete*. For example, when initial investigation shows that water from a drinking water well, or indoor air in an occupied structure, contains release-related chemicals at unacceptable levels, action to protect human health is appropriate. Any such action need not, and in many cases should not, await full characterization of the release. In other cases, removal or treatment of source material, even prior to full characterization, may substantially reduce overall risk, expense, and time to closure. Where such opportunities exist, it is appropriate to pursue them, if doing so does not unacceptably increase associated risks.

Conversely, pre-emptive implementation of a remedy in the absence of adequate characterization does not meet the requirement set forth in [IC 13-25-5-8.5\(c\)](#). Adequate characterization is always necessary to support a *final* decision regarding the necessity of action to protect human health and the environment.

Conceptual Site Models: Definition and General Expectations

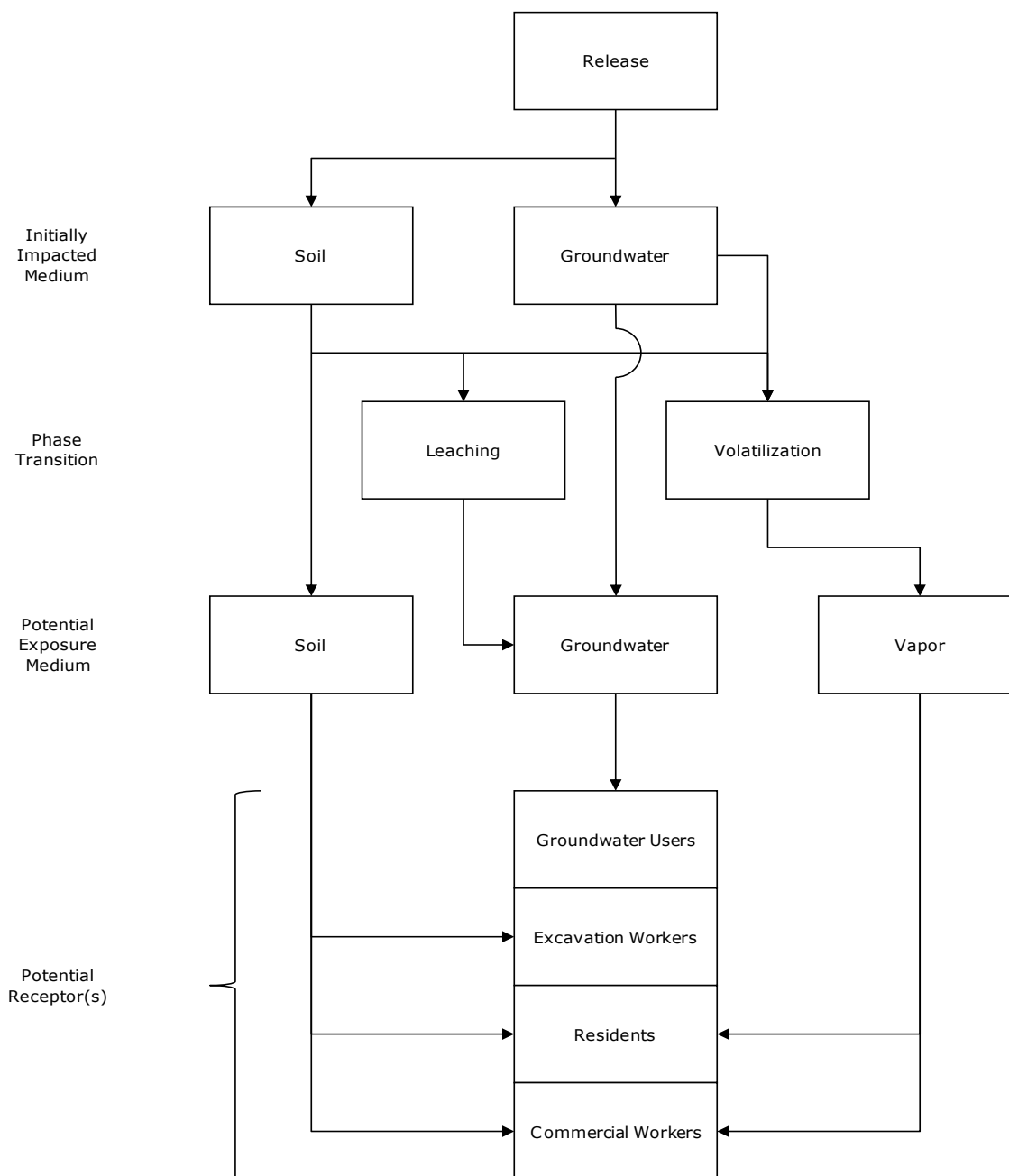
IDEM's evaluation of the adequacy of characterization, risk evaluation, and remedy-related activities relies on submission of supporting documentation by the responsible party or its consultant. One product of project-related activities and document submissions is the development of a **conceptual site model** (CSM) – a comprehensive understanding of the release, including its setting, characterization, an evaluation of risks associated with the release, and any remedy proposed and implemented to address those risks. In this context, the conceptual site model is *not* a specific document, but rather a *conceptual* understanding conveyed by the information obtained throughout the project life cycle. That understanding should increase as the project progresses, reducing uncertainties as new information is obtained and conveyed. CSMs facilitate technical team decision making while supporting stakeholder communication and consensus building. The CSM is an iterative, “living representation” of a release and its environs that helps project teams visualize and understand available information. CSMs are never considered “complete” until final closure occurs.

A sufficient CSM not only captures what is known about a release, but also supports an evaluation of the uncertainty associated with decision-making based on what is currently known. Uncertainty may be addressed in a qualitative fashion, using a weight of evidence approach, or it may be addressed in a more quantitative manner, using statistical concepts and techniques. An uncertainty evaluation may show that a decision can be based on existing information as embodied in the CSM. Alternatively, it may identify data gaps that, if addressed by additional data collection, would allow decision-making to go forward.

CSM Overview Diagrams

The relationships between source(s), affected media, and actual or potential receptors can be depicted in a CSM summary diagram like that shown in Figure 2-A. CSM overview diagrams can help investigators systematically plan investigations, isolate relevant exposure scenarios, evaluate potential risks to specific receptors, and guide selection of any necessary remedies. CSM overview diagrams also help evaluate the sufficiency of the investigation, risk evaluation, and remedy selection (if any). There are many ways to draw CSM overview diagrams (U.S. EPA, 1996b); they need not conform to any format. It is entirely appropriate to tailor CSM overview diagrams to the characteristics of the project and investigation.

Figure 2-A: Example CSM Overview Diagram



Section 2 of this document is organized around identification of the source(s), nature, and extents of releases, but it is also important to identify the anthropogenic and geologic settings of releases. Important components of those settings are described below.

Anthropogenic Setting

Information important in development of a CSM may come from what is already known about the release and its environs. Relevant information will vary according to the characteristics of the facility and release, but typically includes items such as past and present information associated with:

- Facility boundaries and surrounding property use
- Activities conducted at the facility
- Locations of surface structures (e.g., buildings, tanks, etc.) depicted on a map
- Locations of process areas depicted on a map
- Locations and construction of groundwater supply wells and monitoring wells, including drilling logs
- Locations of sanitary sewer and storm water drainage systems (including depth and flow direction within the conduit), including floor drains, drainages tiles, septic tank(s), other underground utilities (telephone, electrical, water, etc.), subsurface disposal field(s), and other underground structures, depicted on a map
- Copies of reports, information, or data related to environmental investigations
- Aerial photographs and analysis or interpretation of such photographs
- Drinking water source(s) for the facility and for adjacent or affected properties
- Location of any significant water withdrawals, including public water supply wells located less than 3,000 feet or within the five-year time of travel of a wellhead protection area
- Identity and locations of sensitive populations adjacent to the facility, including but not limited to daily care facilities (e.g., child care facilities, schools, and senior citizen facilities)

Geologic Setting

Accurate and detailed geologic information is a necessary component of virtually all CSMs, regardless of the type of release. A thorough understanding of the subsurface environment and geologic setting allows the practitioner to place environmental subsurface data in a geologic and hydrogeologic context, and to interpolate geologic characteristics where subsurface data is absent. Geologic and hydrologic information is sometimes already available but is usually collected concurrently with investigation of the release source and extents (see Sections 2.1 and 2.3). Relevant geologic setting information typically includes:

Regional Landforms

Characterization of major landforms (rivers, lakes, topography, karst, etc.) in the vicinity of a release provides a broad understanding of the geologic framework controlling chemical distribution and movement. For example, topography drives surface runoff and regional groundwater typically flows towards streams and rivers. Facility records and visits, and published literature on regional geology, are usually important when developing this understanding.

Subsurface Composition and Structure

While regional landforms provide an overview, subsurface investigation (soil borings, monitoring wells, geophysical investigations, high resolution site characterization, soil analysis, etc.) is important to characterization of the subsurface and provides insight on the relationships between materials surrounding the release. Investigative activities should provide, where relevant to the release and its behavior, detailed descriptions of unconsolidated and consolidated materials; determination of the thickness, depth, and horizontal extent of distinct geologic features (sand lenses, confining layers, bedrock topography, etc.); identification of natural and anthropogenic preferential pathways (sand stringers, utility corridors, karst, soil fractures, etc.); and any correlation of release-related chemical distribution to the project-specific geology. Descriptions of subsurface materials should employ standard terminology [i.e., the Unified Soil Classification System (ASTM, 2017; or as described in U.S. EPA, 1991), or the U.S. Department of Agriculture (USDA) soil texture classification system (USDA, 1951)].

As noted by Schultz et al. (2017), an adequate subsurface investigation will provide the information necessary to:

- Interpret lateral continuity between borehole data and correlate project data in three dimensions
- Identify flow paths and preferential pathways
- Map and predict release-related chemical mass transport (high permeability) and matrix diffusion related storage (low permeability) zones
- Identify data gaps and assess the need for, and cost benefit of, different investigation techniques (e.g., high resolution site characterization)
- Determine appropriate locations and screen intervals for monitoring and remediation wells
- Improve efficiency of groundwater remediation and monitoring

Migration Flow Paths

Groundwater flow and vapor migration dynamics are often sensitive to local and/or regional natural or anthropogenic changes [e.g., precipitation, flooding, pumping, utilities; see IDEM (2021b) for additional guidance and discussion], and typically requires regular monitoring to characterize the magnitude and significance of changes in flow. An adequate understanding of the migration of vapors from release-related chemicals will typically involve delineation of vapors and concentration gradients within affected and relevant permeable units in the vadose zone, noting that vapors may not flow in the same direction as groundwater. In some cases, this may involve delineation in more than one permeable unit, or vertical delineation within the vadose zone (e.g., to determine the extent to which vapors arising from a groundwater source attenuate before reaching a structure.) Factors that may affect this include source concentration, source depth, soil matrix properties (e.g., porosity and moisture content), anthropogenic changes, and time since the release occurred.

An adequate understanding of these processes should relate all the components of the geologic setting to the distribution of all phases of the release-related chemicals (e.g., isoconcentration maps) to provide a clear understanding of the mechanisms controlling their migration through saturated and unsaturated media, and areas where saturation levels fluctuate. This can help guide further investigative efforts; identify, evaluate, and control exposure; and evaluate the applicability of various remediation techniques.

2.1 Task One: Identify Release Source(s)

In this document, the unmodified word **source** may take on one or more meanings, depending on context.

Source facility refers to the building, land, or enterprise used for one or more purposes (e.g., gasoline sales and storage, dry cleaning, manufacturing, etc.), where the release occurred. Source facility can also apply to an area within a larger property.

Source point refers to the physical location where release-related chemicals first entered the environment. Examples of source points include a hole in an underground storage tank, a leaky joint in an underground pipe, the location of a surface spill, etc. There can be more than one source point at a source facility.

Source area refers to the two-dimensional map projection of a three-dimensional volume where release-related chemicals are present in one phase at concentrations high enough to enable them to readily transfer to a different phase at concentrations that require a remedy. Examples of this include:

- An area underlain by chemicals in soil that are leaching to groundwater at concentrations that require a remedy
- An area underlain by chemical concentrations in groundwater that volatilize into soil gas at concentrations that require a remedy
- An area underlain by nonaqueous phase liquid (NAPL) that is feeding a plume in groundwater that requires a remedy

Note that chemicals volatilizing from groundwater may do so at a considerable distance from the source point or source facility. Similarly, chemicals released to soil may dissolve into groundwater, travel some distance, and then resorb to soil, where they may subsequently dissolve into groundwater at unacceptable concentrations. Therefore, source area identification may not be possible until delineation activities are well underway or complete.

Source mass refers to the mass of release-related chemicals in source areas.

Some or all these aspects of the source concept will be important for every release.

2.1.1 Basis for Requirement

Source identification is necessary for effective implementation of [IC 13-25-5-8.5\(c\)\(1\)](#), which requires adequate characterization of the nature and extent of releases. For example, some knowledge of the source facility or likely source facility is necessary to decide where to look for release-related chemicals.

There may be instances where the age or diffuse nature of a release makes locating a source point infeasible. Where knowledge of the source point is available, that information can help focus investigations, particularly when the release occurs at a large facility. Knowledge of the source area is an important component of understanding how and when chemicals are likely to move, what media may be affected by the release, and ultimately how receptors may be affected. Estimates of source mass may be important in the design of certain remedies. While it may not always be necessary or even possible to identify every aspect of sources, source identification should be comprehensive enough to enable adequate release characterization, risk evaluation, and (when necessary) remedy selection and implementation.

2.1.2 Identifying Release Sources

Identification of source facilities, source points, source areas, and source mass are different problems, although some information may help solve more than one of them. Source identification often starts with an evaluation of source facility activities, review of previous investigative work, and a facility visit.

2.1.2.1 Identifying Source Facilities

Means of identifying source facilities include one or more of the following:

- Release reports submitted to IDEM or other agencies
- Environmental investigation reports that contain evidence of releases or potential releases, including reports generated for nearby properties or facilities
- Evidence of releases (stained soil, stressed vegetation, etc.) observed during facility visits
- Interviews with current or past owners and employees, local fire and police departments, county health officials, and facility neighbors
- Records of operational processes, chemical use, and waste storage and disposal practices, including regulatory databases and files maintained by the United States Environmental Protection Agency (U.S. EPA), IDEM, and local health departments
- Aerial photographs, fire insurance maps, property tax or land title records, city directories, satellite imagery, and geographic information system maps
- Other relevant resources

2.1.2.2 Identifying Source Points

Means of identifying source points include one or more of the following:

- Release reports submitted to IDEM or other agencies
- Environmental investigation reports that contain evidence of releases or potential releases
- Evidence of releases (stained floors or soil, stressed vegetation, etc.) observed during facility visits
- Locations of chemical and waste storage and disposal areas, operational areas, maintenance areas, drains, sumps, oil/water separators, parts cleaners, electrical transformers, pits, ponds, lagoons, septic systems, etc.
- Records pertaining to operational processes, chemical use, and waste storage and disposal practices
- Interviews with current or past owners and employees, local fire and police departments, county health officials, and facility neighbors
- Other relevant resources

2.1.2.3 Identifying Source Areas

Identifying and, where necessary, determining the extent(s) of source areas can help explain the behavior and distribution of release-related chemicals, and may also aid in the design of remedies. There are several kinds of source areas:

A soil source area exists wherever release-related chemicals in soil leach to groundwater and cause dissolved concentrations of those chemicals to exceed unconditional groundwater remediation objectives, or when those chemicals volatilize into soil gas at concentrations that cause vapors to exceed unconditional vapor remediation objectives.

A nonaqueous phase liquid (NAPL) source area exists wherever release-related chemicals in NAPLs sorb to soil at concentrations that cause soil to exceed unconditional soil remediation objectives, dissolve into

groundwater at concentrations that cause groundwater to exceed unconditional groundwater remediation objectives, or volatilize into soil gas at concentrations that cause vapors to exceed unconditional vapor remediation objectives.

A groundwater source area exists wherever release-related chemicals in groundwater volatilize into soil gas at concentrations that cause vapor to exceed unconditional vapor remediation objectives. It is unusual for release-related chemicals in groundwater to cause concentrations in soil to exceed unconditional soil remediation objectives, but if this happens, then the area where release-related chemicals in groundwater does so should be considered a source area.

It is very unusual for vapor concentrations to be high enough to cause concentrations in other media to exceed unconditional remediation objectives for those media, but if this happens, then the area where release-related chemicals in vapor does so should be considered a source area.

Where necessary, IDEM recommends delineating soil-to-groundwater source areas by evaluating the leaching potential of soil samples using a leaching test, such as the synthetic precipitation leaching procedure (SPLP) or a similar technique that meets project-specific DQOs. Other technologies that may prove useful when it is necessary to delineate various types of source areas (especially NAPL source areas) include membrane interface probes or laser-induced fluorescence devices, typically in conjunction with sampling at locations indicated by those technologies. IDEM recommends delineating groundwater-to-vapor source areas by collecting soil gas samples from the vadose zone just above the groundwater table.

2.1.2.4 Determining Source Mass

For many releases, knowledge of the source facility, point, and/or area, as well as observation of release system behavior, will be sufficient for purposes of characterization, risk evaluation, and remedy selection and implementation. However, for some releases, and especially for certain remedies, an estimate of source mass will be necessary. If the release is of a known quantity, use that as the source mass. Otherwise, derive a mass estimate using sample concentration data and knowledge of the spatial distribution of those concentrations.

2.1.3 How IDEM Will Evaluate Release Source Identifications

Is adequate evidence presented to identify one or more of:

Source facility or facilities

- Items listed in Section 2.1.2.1, as relevant

Source point(s)

- Items listed in Section 2.1.2.2, as relevant
- Sampling data showing spatial concentration gradients

Source area(s)

- Items listed in Section 2.1.2.3, as relevant
- Sampling data showing spatial concentration gradients
- Leaching test or soil gas data, if relevant

Source mass

- Known quantities of release-related chemicals, or mass estimates derived from sample concentration data and knowledge of the spatial distribution of those concentrations

2.2 Task Two: Determine the Nature of Release-related Chemicals

The **nature** of release-related chemicals refers to their identity and concentrations in various media. Determining the nature of release-related chemicals requires an understanding of the source of the release and the use of appropriate sampling and analysis procedures. This section provides guidance on chemicals typically associated with certain types of facilities or operations, sample collection, handling, and analysis, and appropriate quality control procedures, including documentation of results. It also describes how IDEM will evaluate the sufficiency of efforts to identify and quantify release-related chemicals. It is not a complete compendium of acceptable procedures. Other procedures may also produce acceptable results, and IDEM will evaluate use of those procedures on their merits.

2.2.1 Basis for Requirement

[IC 13-25-5-8.5\(c\)](#) requires adequate characterization of the nature and extent of release-related chemicals with respect to remediation objectives. Sampling is vital to development of an adequate CSM and underpins any understanding of the distribution and concentrations of release-related chemicals, whether receptors might be affected, and the pathways by which release-related chemicals may reach receptors. Even modeling requires project-specific sample data for calibration and validation.

2.2.2 Sample Planning

Careful planning is essential in executing environmental projects, and this is especially true with respect to the sample planning phase. A Quality Assurance Project Plan (QAPP) documents the sample planning process. QAPPs describe the decision-making process, plans for data acquisition, quality criteria, and procedures for assessing investigation results. The scope of QAPPs will generally increase with the complexity of the projects they support. New information and/or changes in project scope may also necessitate revisions to the QAPP.

The Data Quality Objectives Process (DQOP) establishes project quality objectives and criteria. The DQOP is used for systematic planning to collect environmental data of known quality and quantity to support decisions. The seven-step DQOP defines the problem, identifies the decision needed, identifies the inputs of the decision, defines the boundaries, develops a decision rule, specifies limits for decision errors, and optimizes the design for obtaining data.

The DQOP is also iterative. Project quality objectives and criteria are reviewed and updated as additional information becomes available. Additional information may and often does change the objectives of a project.

A complete description of QAPPs and their components is beyond the scope of this document. U.S. EPA (2000, 2002, 2002b, 2006, and 2006b) provides guidance on QAPP development and implementation. A program-specific generic QAPP (such as the [UST Program QAPP](#)) can be referenced with a notation of any deviations in any given project. Deviations from the generic QAPP can be documented in a project-specific Sampling and Analysis Plan (SAP). A project-specific SAP specifies where and when samples will be collected, the number of samples to be collected, sampling method(s) for various media, and procedures for sample preservation during transportation and storage.

Choosing Areas to Sample

Sampling areas depend on investigation objectives. Investigation objectives vary widely, and so will the sampling areas necessary to pursue those objectives. Possible investigation objectives include:

- Determine the extents of release-related chemicals
- Determine representative concentrations in a decision unit
- Determine background concentrations of release-related chemicals
- Collect information needed for remedial system design
- Demonstrate achievement of remediation objectives in a decision unit

There are many other possibilities. Whatever the investigation objective(s), reports should include the rationale and supporting evidence for selection of specific sampling areas. Note that different decision units may have different likely future exposures (e.g., paved parking, places used by sensitive populations, break area, factory floor, etc.). Separate sampling plans for each identifiable exposure area allow subsequent separate exposure evaluations in those areas, rather than using the same exposure assumptions across the entire release area.

Sampling Design

There are many possible ways to place sample locations across a release area. This document focuses on two general approaches, described below. Other approaches may be preferable for some projects. IDEM will evaluate other approaches on their merits. Whatever the approach, the number of samples necessary for an adequate characterization is project specific.

Judgmental sampling uses professional judgment and existing knowledge of the release to place sample locations. Judgmental sample placement typically starts near a source point or facility and steps out until sample locations approximate the extents of release-related chemicals. However, it is also possible to start near potential receptors and step in toward a source. Stepping in may be preferable when there is a concern that receptors are experiencing exposure to release-related chemicals, because it may allow earlier identification of any unacceptable exposures and therefore earlier implementation of a remedy to address those exposures. Delineation efforts that begin by stepping in will still need to delineate extents, often by stepping out once initial step-in activities are complete. The effectiveness of judgmental sampling depends on the quality of the information used to guide sample placement, but if good information is available regarding the likely locations of release-related chemicals, extents delineation using judgmental sample placement is often less expensive than alternatives.

Systematic sampling places samples at fixed intervals beginning from a random starting point (as along a drainage way, excavation wall, or perimeter) or according to a predefined pattern that distributes samples uniformly over an area. Systematic methods are suitable for any project but are especially useful for projects where there is limited information about the likely distribution of release-related chemicals (e.g., fields, vacant lots, or sediment deposition zones). It is appropriate to use the results of systematic samples to calculate representative concentrations across decision units. Because it starts with less information than the judgmental approach, systematic sample placement often requires more sample locations than does judgmental sample placement to achieve adequate coverage of the area under investigation. In some cases, it may be possible to use pre-existing information (e.g., topography or regional groundwater flow direction information) to modify the systematic sampling array in a way that reduces the required number of sample locations. In other instances, a systematically placed sample may reveal release-related chemicals at concentrations exceeding unconditional remediation objectives, thus enabling that location to serve as the starting point for a stepping out procedure.

Sometimes it is useful to combine the two approaches. For example, judgmental sampling may identify specific areas of concern, followed by systematic sampling within those areas. The resulting exposure

estimate may be more representative than judgmental sampling of release-related chemical concentrations in a decision unit. U.S. EPA (2002c) includes guidance on numerous sampling designs.

Appropriate sample media will depend on project-specific factors and the exposure scenarios under evaluation. For example, IDEM may not require collection of surficial soil samples for characterization of subsurface releases. Conversely, a surficial release followed immediately by removal might achieve closure with only post-removal surficial soil samples. IDEM anticipates that adequate characterization of most releases will require analytical data for both soil and groundwater, and that vapor phase samples will also be required for some types of releases.

Note that IDEM may conduct field audits during any sampling event⁵. The scope of audits may vary by program and may include split sampling. For this reason, IDEM should be provided a minimum of two weeks advance notice of proposed field activities.

When there is incomplete or unreliable information about activities at a facility, IDEM programs may specify pre-defined lists of chemicals for analysis. For example, the comprehensive list for Resource Conservation and Recovery Act (RCRA) Subtitle C facilities includes Appendix VIII to [40 CFR 261](#) and Appendix IX to [40 CFR 264](#). Less comprehensive lists, such as the Comprehensive Environmental Response, Compensation, and Liability Act target compound list or target analyte list may be more appropriate if they include release-related chemicals. Ecological risk assessment may involve evaluation of different or additional release-related chemicals than those relevant to human health risk assessment.

The types of release-related chemicals will dictate which analytical methods are most appropriate for different media. Table 2-A summarizes analytical recommendations for various facilities and release types.

⁵ Under authority in [IC 13-14-2-2](#), [IC 13-23-13-12](#), [IC 13-24-1-6](#), and [IC 13-25-4-6](#).

Table 2-A: Chemicals Often Associated with Various Facilities and Releases

Release Type/Industry	Chemical or Chemical Class									
	VOCs	PAHs ¹	PCBs	SVOCs	Metals	CVOCs ³	Phenols	Cresols	Cyanide	Misc.
Dry Cleaning Industry	X ⁴					X				
E-85 Fuel	X ⁵									
Manufactured Gas Plants	X	X	X ⁷		X ⁶		X	X	X	X ²
Auto Salvage Yard	X	X	X		X ⁶					X ²
Metal Finishing	X			X	X ⁶				X	X ²
Gasoline Range Product ⁹	X ^{5,8}				X ⁸					
Diesel Range Product ¹⁰	X	X								
Hydrocarbon Oil Range Product ¹¹		X								
Waste/Used Oil; Unknown Petroleum Product	X ⁸	X								

Notes:

¹Polyaromatic hydrocarbons (PAHs) should include all chemicals on the U.S. EPA SW-846 Method 8310 analyte list.

²For manufactured gas plants, include pH and ammonia. For auto salvage yards, include pH, asbestos, ethylene glycol, and propylene glycol. For metal finishers, include pH.

³Chlorinated volatile organic chemicals (CVOCs) include, among other chemicals, tetrachloroethene, trichloroethene, 1,1,1-trichloroethane, 1,2-cis- and 1,2-trans-dichloroethenes, and vinyl chloride.

⁴Analyze full VOCs if solvents other than tetrachloroethene, trichloroethene, and/or 1,1,1-trichloroethane were used.

⁵Include naphthalenes (naphthalene, 1-methylnaphthalene, 2-methylnaphthalene)

⁶Contact IDEM for list of metals.

⁷Where electrical generation occurred, or if transformers are/were present, analyze for and report total polychlorinated biphenyls (PCBs) and Aroclors.

⁸Report total lead and lead scavengers (1,2-dibromoethane and 1,2-dichloroethane) for aviation gas and racing fuel releases, or when automotive gas was used or stored before January 1, 1996, unless previous investigations performed at the property and available in IDEM files have ruled out lead and lead scavengers.

⁹Includes automotive gas, aviation gas, racing fuel, Stoddard solvent, naphtha, JP-4, and ethanol fuel

¹⁰Diesel #1 and 2, kerosene, JP# 5, 7, & 8, light oil, heating oil, and biodiesel <100%

¹¹Fuel oil #4, #5, #6, bunker oil, virgin motor oil, hydraulic oil

2.2.3 General Sampling Guidance

Sampling is the process of collecting an aliquot of some medium for analysis, with the intent of using the resulting concentration to represent, singly or in concert with other results, a representative concentration in a decision unit. **Sampling procedures matter.** If samples are not collected properly or are not collected in appropriate locations, they will not adequately represent the decision unit under investigation, and subsequent laboratory work may be pointless.

In general, minimize the possibility of cross-contamination by using disposable sampling equipment. If disposable sampling tools are not available or not practical, specify the cleaning procedures used. Wear clean sampling gloves at each sampling point. Wash reusable sampling equipment with an appropriate detergent or cleaning solution (e.g., Liquinox® or equivalent), and rinse before each use. Adequate sample volume must be collected to allow for the analysis of release-related chemicals.

Several field-portable instruments and detectors (for example photoionization detector, flame ionization detector, colorimetric test kits, immunoassay kits, portable gas chromatographs, x-ray fluorescence units, etc.) can be used to screen environmental media. All field instruments have advantages and limitations. The instrument used must be capable of detecting release-related chemicals and users must be familiar with and follow operating instructions recommended by the manufacturer. SAPs should describe the field instruments and their use as appropriate for the release-related chemicals. The discussion should also include any limitations that could affect the use of an instrument (e.g., chemicals not detected, moisture, cold weather, etc.)

A project SAP should describe proper disposal of purge water, borehole cuttings, or other investigation-derived wastes (IDW). IDW management must ensure protection of human health and the environment and comply with other applicable state and federal regulations. See U.S. EPA (1992) for guidance on management of IDW.

IDEM may request documentation that persons conducting sampling have received adequate training to do so. Training records and field notes are examples of such documentation.

2.2.4 Sampling Soil

There are many possible reasons for sampling soil. Examples include:

- Delineating horizontal and vertical extents of release-related chemicals
- Evaluating soil exposure risk
- Identifying source location(s), including NAPL
- Guiding placement of monitoring well screens
- Guiding remedy design, selection, and implementation
- Evaluating the adequacy of a remedy
- Meeting program-specific requirements

Depending on their purpose, soil samples may be collected from the ground surface, below the surface, and/or from excavation walls and bottoms. Collect separate soil aliquots or sufficient sample volume to allow determination of percent solids to enable reporting soil sample results on a dry weight basis.

When investigating a surface release, it may be necessary to begin soil sampling at the ground surface, proceeding downward until soil exposure is adequately understood. This may involve collecting more than one surface or near surface sample. If release-related chemicals extend into the subsurface, additional samples may be necessary to understand their distribution and associated risk potential. When release-related chemicals are likely confined to the subsurface (e.g., following a release from an underground storage tank), surficial soil samples may not be necessary.

Physical Description of the Subsurface

The importance of accurately describing the subsurface environment cannot be overstated. Soil properties strongly influence the distribution of release-related chemicals in the environment, regardless of the nature of the release. Comprehensive description of subsurface materials (including fill) helps predict release-related chemical distribution in various horizons and supports the rationale for soil sampling locations. Therefore, soil and other subsurface materials (including fill) need to be thoroughly described to understand where to collect representative samples. When describing soil, start by using a standardized soil classification system (e.g., ASTM, 2017; USDA, 1951). These systems provide a description of the soil composition and texture only. Additional important characteristics when evaluating soil cores for environmental characterization include the following: soil structure, sedimentary features, consistency, moisture content (qualitative determination), boundary or contact, and zones of secondary porosity. Munsell soil charts (Munsell Color, 2010), or a suitable alternative, are useful when evaluating and describing soil color. U.S. EPA (1991) provides a comprehensive listing of information needed and types of field testing available to describe soil for site characterization.

Choosing Soil Sampling Locations

Soil sampling usually begins in the release-related chemical source area(s) where the highest concentrations are likely to be encountered and continues in all directions (including vertically) until sample results meet appropriate remediation objectives. Sample spacing should consider both the nature of the subsurface and the expected behavior of the release-related chemicals. It may be necessary to sample saturated soil, particularly to evaluate release-related risks if soil at depth is likely to be brought to the surface and exposed, or when it is necessary to derive total release-related chemical mass. Refer to Section 2.3.2 for additional explanation about extents investigation.

The following conditions may identify one or more subsurface soil locations within borings with the highest potential to contain release-related chemicals, whatever the purpose of the sampling:

- Locations that elicit the highest field screening result
- Soil that is stained, discolored, oily, shiny, or visibly altered
- Soil in strata likely to contain release-related chemicals based on chemical characteristics and soil type (e.g., potential accumulation of metals in clay or silt, accumulation on the top of clay strata or at the bottom of sand strata, or other locations *based on the expected behavior of the release-related chemical in the environment*)

In the absence of positive screening results or visual cues, samples from borings submitted for laboratory analysis should be from a material within the core interval displaying the greatest apparent effective porosity or immediately above water bearing zones. Other options include analyzing a sample from each stratum, or from each two-foot interval.

Sampling Excavation Walls and Bottoms

Refer to [329 IAC 9-6-2.6](#) for UST excavation confirmatory sampling requirements. These sampling requirements may also be used as guidelines for non-UST confirmatory excavation sampling.

Sampling Volatile Organic Chemicals in Soil

As their name suggests, volatile organic chemicals (VOCs) evaporate readily. This property can lead to significant VOC losses during sample collection and handling, and result in biased analytical data. When sampling VOCs in soil, use U.S. EPA SW-846 Method 5035A (as updated) to minimize VOC loss. Appendix A of Method 5035A describes several options for collection, preservation, and storage of samples for VOC analysis. However, the specialized containers and preservation techniques described in Method 5035A may be unnecessary for samples collected within areas where release-related chemicals are known or suspected to exceed remediation objectives, if the sampling method meets DQOs.

Use screening instrument results, professional judgment, and knowledge of the release-related chemicals and soil to decide which samples to send to the laboratory. To minimize VOC loss, collect subsamples from the soil core as quickly as possible, taking special care to limit exposure and disaggregation of the soil. Any samples not sent to the lab are considered investigation-derived waste and should be treated as such. The field record should clearly document reasons for choosing samples for lab analysis.

Photoionization detectors (PIDs) detect most VOCs and are probably the most used VOC field screening instrument at both gasoline and chlorinated solvent releases. PIDs are suitable for chemicals with an ionization energy less than the PID's lamp voltage – typically 10.6 electron volts. Higher voltage PID lamps exist and can somewhat extend the range of detected chemicals. A flame ionization detector (FID) may be a suitable alternative when working with unknown chemicals, or when the chemicals have higher ionization potentials than the PID lamp. FIDs may prove especially useful when screening for diesel fuel and weathered to heavy petroleum products.

When sampling under this procedure:

- Allow sufficient time between subsurface soil core retrievals to avoid sampling backlogs
- Protect soil cores from direct sunlight, rain, wind, etc.
- Collect all subsamples as soon as possible after removing the soil core from the borehole, not from soil that has been exposed for more than a few minutes
- Collect and store intermediate subsamples from the soil core in plastic or glass containers with zero headspace in a cooler with ice while completing any field screening
- Remove any intermediate subsample container selected for analysis from the cooler and create a fresh surface in the intermediate subsample prior to collecting a final subsample to send to the lab
- Document procedures for collecting the intermediate subsample, the separate subsample used for field screening, and the final subsample

IDEM (2021a) contains additional information on sampling soil for VOCs. IDEM will consider alternatives to the procedures and equipment described in Method 5035A and other related guidance on a project-specific basis.

Sampling Semi-volatile and Non-volatile Chemicals in Soil

Commonly encountered semi- and non-volatile release-related chemicals include metals, PCBs, and PAHs. Releases with these types of chemicals can be more difficult to investigate because there are sometimes no obvious indications in the soil. Semi-volatile chemicals may volatilize enough to make field screening possible with an appropriate ionization detector (e.g., PID or FID). Field screening for metals is usually completed using x-ray fluorescence. There is no effective way to field screen for PCBs. These types of chemicals are less mobile and tend to accumulate in soil, so surface soil sampling is often an important component of investigation for these chemicals. See SW-846 (U.S. EPA 2019d) for specific guidance on collecting and analyzing samples for metals, PCBs, and PAHs.

Evaluating Leaching Potential

Release-related chemicals sorbed to vadose zone soil or NAPLs may move down through the soil column (leach) and cause or contribute to concentrations of those chemicals in groundwater that exceed unconditional remediation objectives. Evaluating leaching potential is of concern when release-related chemicals have not had time to leach to groundwater, or when vadose zone NAPL or impacted soil are overlain by concrete, asphalt, buildings, or other barriers to precipitation infiltration. In the latter case, the results of such evaluation are an important line of evidence when deciding whether the existing or similar barrier should remain in place to prevent creation of, or significant contributions to, any release-related chemical plume in groundwater.

When evaluating leaching potential, consider using the synthetic precipitation leaching procedure (SPLP, U.S. EPA Method 1312) or a similar method. When using SPLP, collect a minimum of three vadose zone soil samples from the area of highest release-related chemical concentration and analyze them using SPLP. Existing analytical information, knowledge of stratigraphy, and professional judgment are also important when selecting the locations and appropriate number of samples. SPLP uses a blend of dilute inorganic acids to simulate acid rain and its effects on chemicals in soil (U.S. EPA, 1994). The method produces a leachate solution, and the laboratory reports the concentrations of chemicals in that solution.

2.2.5 Sampling Groundwater

Once release-related chemicals reach the groundwater they can begin to move downgradient and create additional exposure risks. Because chemicals dissolved or suspended in groundwater are more mobile, release-related chemicals can extend some distance from the original source area.

There are many possible reasons for sampling groundwater. Examples include:

- Delineating horizontal and vertical extents of release-related chemicals
- Evaluating risk to drinking water
- Identifying source location(s), including NAPL
- Guiding remedy design, selection, and implementation
- Evaluating the adequacy of a remedy
- Meeting program-specific requirements

Appropriate groundwater sampling procedures and equipment will vary depending on local conditions and individual program requirements. Yeskis and Zavala (2002) provides general guidance on preparing for and performing groundwater sampling. U.S. EPA (2005) addresses sampling groundwater from direct-push wells. IDEM (2009) addresses the use of monitoring wells and groundwater grab samples. All sampling methods and equipment must be clearly documented, including purge criteria and field readings, to allow for verification of sampling procedures and data interpretation.

Choosing Groundwater Sampling Locations

Thoughtful and effective groundwater sampling begins with the physical description of the subsurface noted in Section 2.2.4. To collect representative samples, the groundwater investigation must consider both the physical subsurface environment and the behavior of the release-related chemicals in solution. Since groundwater movement allows release-related chemicals to spread beyond the source area, it is important to understand the direction and dynamics of the groundwater flow.

Groundwater sampling usually begins near the water table within or as near as possible to known release-related chemicals above unconditional remediation objectives. Refer to Section 2.3.4 for additional explanation about extents investigation. Sample spacing should consider both the nature of the subsurface and the expected behavior of the release-related chemicals. Samples should also be placed

near likely receptors and/or other places where release-related chemical concentrations must be at or below certain concentrations.

Occasionally, groundwater does not accumulate in borings or wells even though there are indications of saturation in the physical description of the subsurface. This typically occurs in areas of dense, fine-grained material, karst, and shallow bedrock. Groundwater accumulates slowly in dense, fine-grained materials and samples from borings may not be possible while using procedures outlined in [312 IAC 13-5-1\(e\)](#), especially during dry periods, and permanent monitoring wells may be needed for groundwater sampling data. Monitoring wells that are consistently dry typically require reinstallation with a deeper screened interval. See IDEM (2021b) for guidance on groundwater sampling in karst and shallow bedrock, respectively.

Groundwater Samples From Borings

It is often useful to collect grab groundwater samples from boreholes prior to installing permanent monitoring wells. Groundwater grab sample data is typically used for screening purposes, initial extents determinations, directing further investigation, or as a line of evidence in combination with groundwater monitoring well data. Release-related chemicals in saturated unconsolidated deposits typically are distributed in relatively thin layers of higher-permeability material rather than as a homogeneous solution distributed throughout the saturated zone. Similarly, release-related chemicals in bedrock typically are distributed preferentially in fractures, voids, and higher permeability zones, rather than uniformly throughout the bedrock matrix. Therefore, it is important to provide as much detail as possible about where within the boring the sample was collected. This inhomogeneity of the subsurface is why groundwater grab sample results generally need to be supported with other lines of evidence.

Groundwater grab samples can be collected using a variety of methods. Method choice depends on the type of drilling equipment and sample interval. Groundwater grab samples are often turbid and analytical results may not be representative of dissolved chemical concentrations. Purging multiple borehole volumes may reduce turbidity in samples. However, under most circumstances (e.g., when limited groundwater availability or the sampling technique does not allow it), purging may not be possible. IDEM (2005) addresses filtration of turbid samples.

Groundwater Samples from Wells

Time series data from monitoring wells is useful because groundwater moves and inhomogeneity in the subsurface can create wide variability in sample results from individual locations. Permanent monitoring well construction standards are outlined in [312 IAC 13-8-3](#). However, in order to provide representative samples, monitoring wells also need to be thoughtfully located with respect to source area, groundwater flow direction, and receptors, as well as appropriately screened to best evaluate release-related chemical distribution within an interval of interest.

Svavarsson et al. (1995) compared low-flow sampling and sampling using bailers and found no significant differences in recovery of volatile organics. However, low-flow (also called “micro-purge” or “minimal drawdown”) sampling procedures may improve groundwater sample quality. Puls and Barcelona (1996) is the primary U.S. EPA guidance on low-flow procedures. A non-purge sampling option may be suitable for petroleum releases; IDEM (2021a) contains low-flow and non-purge sampling guidance.

Groundwater sampling equipment should be capable of meeting project DQOs. Peristaltic pumps, high-speed submersible pumps, and inertial lift pumps may cause excessive agitation of groundwater samples, and IDEM does not recommend their use when collecting samples for VOC analysis (Nielsen 2005; Yeskis and Zavala 2002; U.S. EPA 2005). However, use of a peristaltic pump may be acceptable in some instances discussed in IDEM (2021a). Passive sampling devices that meet a strict set of criteria (ITRC 2007 and IDEM 2021a) also may be acceptable for long-term groundwater monitoring. The [Federal](#)

[Remediation Technologies Roundtable](#) includes descriptions of many types of sampling equipment and a matrix that compares the advantages and disadvantages of different types of sampling equipment.

When historical groundwater data is available, sample collection should begin with those wells containing the lowest concentrations of release-related chemicals and proceed to wells with increasingly higher concentrations. Otherwise, begin with wells upgradient of likely source points, continue with downgradient wells, and finish with wells in or closest to suspected source points. If NAPL is suspected or if strong odors are present in a well, attempt to measure NAPL thickness. Sampling groundwater at monitoring wells with measurable NAPL is typically not required. However, sampling of wells with trace amounts (i.e., less than 0.1 feet) of NAPL may be appropriate if it is necessary to address a clearly defined project-specific objective.

IDEM recommends using laboratory supplied sampling containers and preservative(s) for groundwater samples. Collect enough samples to allow for possible breakage and quality assurance needs. For VOC analysis, groundwater samples must be collected in 40 ml glass vials with Teflon® septa. The vials may be either preserved with concentrated hydrochloric acid or they may be unpreserved. Preserved samples have a two-week holding time, whereas unpreserved samples have only a seven-day holding time. Groundwater with dissolved carbonates may effervesce and produce bubbles if placed in a vial with hydrochloric acid. This will render the sample unacceptable. In this case, unpreserved vials should be used, and arrangements should be made with the laboratory to ensure that they can meet the shorter sample holding times. A trip blank is recommended when collecting samples for VOC analysis to document any sample contamination attributable to shipping and field handling.

2.2.6 Sampling Vapor

Because many release-related chemicals are volatile, they release vapors into the pore spaces of unsaturated soil. These vapors can then travel into breathing spaces and create unacceptable risks. Investigation and delineation of vapors in exterior soil gas is useful to determine whether potential current or future risks need to be addressed. Though perhaps not as well understood as soil and groundwater sampling procedures, vapor sampling has been underway in Indiana and elsewhere for well over a decade. Detailed guidance on many vapor sampling procedures is available in U.S. EPA (2015, 2015b) and the documents they reference. However, because vapor sampling is less established than soil and groundwater sampling, IDEM provides additional explanation on sampling procedures in the text that follows.

Indoor air sampling paired with subslab soil gas (SGss) or crawl space air sampling helps establish the relationship between concentrations of release-related chemicals in subsurface vapor and indoor air. It is a strong line of evidence that may also help reveal sources of release-related chemicals within the building. IDEM does not recommend sampling only indoor air because indoor sources may make interpretation of the results difficult.

Preferential pathways, including conduits, can allow vapors to reach indoor air without significantly affecting the subsurface beneath a building. For this reason, vapor characterization must include consideration of, and in some cases, sampling in preferential pathways, including conduits. Refer to Section 2.2.6.4 for more information regarding appropriate situations for sampling within preferential pathways.

Exterior soil gas (SGe) sampling is appropriate for determining a soil vapor source, delineating soil vapor plumes, use as a stand-alone investigative tool to evaluate vapor intrusion potential at structures whose owners do not grant access for subslab sampling, during preferential pathway backfill investigations (in limited circumstances), or when evaluating vapor intrusion potential at undeveloped properties (depending on the SGe sampling density).

As noted in U.S. EPA (2015) there are several types of vapor sampling technologies, and it seems likely that new technologies will continue to appear and evolve. Consistent with its treatment of soil and groundwater sampling procedures, the Risk-based Closure Guide provides only a summary of some standard approaches to vapor sampling. A short, annotated list of some common technologies follows, but it is not complete. IDEM will accept vapor data collected using any type of vapor sampling technology that meets project specific DQOs.

- Evacuated canisters use a vacuum to draw in whole air samples. Batch-certified clean canisters are generally acceptable, though some users may prefer individually certified clean canisters as an additional safeguard against false positives. Canisters usually arrive from the laboratory equipped with flow regulators and a vacuum gauge. Laboratories typically pre-set flow regulators, so it is important to determine appropriate flow rates prior to delivery. Samples collected into canisters are usually analyzed by U.S. EPA Method TO-15 or its equivalent.
- Active sorbent samplers that use pumps to mechanically draw air through the sorbent, or passive sorbent samplers that rely on diffusion from the air, are often able to function over longer time periods than evacuated canisters and may have significant advantages for evaluating long-term vapor exposure risk. Both sorbent sampling approaches are typically coupled with U.S. EPA Method TO-17.
- Tedlar® bags are only acceptable in very specific circumstances, due to concerns about leaks, pressure changes during transport, cleanliness certification, and short holding times (48 hours). They can be used to collect high concentration (parts per million by volume) grab samples. Their use in projects where low concentrations (parts per billion by volume) are expected is limited due to potential leaks and bag cleanliness. Tedlar® bags can be used as a screening tool for initial site investigations and monitoring.

IDEM recommends the use of evacuated canisters or sorbent samplers for sample collection if the data is to be used for risk assessment. If consistent with project DQOs, options described above (or equivalent) can be used to collect samples to allow for on-site analysis using analytical techniques that can generate data to support project objectives.

There are many other possible techniques, such as:

- High volume sampling
- Building pressure manipulation
- Triggered/event-based sampling (indicators, tracers, surrogates)
- Continuous sampling [e.g., on-site gas chromatography/mass spectroscopy (GC/MS)]
- Portable GC/MS (e.g., discrete samples with Tedlar® bags)
- Large sample sets to characterize variability (possibly calculate upper confidence limit of the mean)

Except for building pressure manipulation, use of these techniques will need to include consideration of seasonality. The optimal approach will depend on circumstances and may change as the investigation proceeds. IDEM will evaluate alternate approaches on their merits, but because the conclusions of many vapor intrusion investigations are based on a relatively limited data set that typically represents variable vapor concentrations, IDEM has determined that conservative approaches are generally preferable when investigating vapor risk.

Note that smoking, use of certain household products, and similar activities near vapor sampling areas may compromise analytical results. Additionally, understanding heating, ventilation, and air conditioning (HVAC) settings for commercial and industrial facilities may be pertinent to the vapor CSM and conditions should be noted during paired vapor intrusion sampling events as described in IDEM (2021b).

2.2.6.1 Soil Gas Sampling: General Considerations

Soil gas samples are air samples collected from within the vadose zone. Exterior soil gas (SGe) samples are from the vadose zone outside a building footprint, while subslab soil gas (SGss) samples are from the vadose zone underneath the basement or slab of a building. In very general terms, collecting soil gas samples requires installing a probe into the vadose zone, drawing gas out of the vadose zone, and collecting that gas for analysis (U.S. EPA 2015). Appropriate procedures vary somewhat depending on whether the soil gas is exterior (Section 2.2.6.2) or subslab (Section 2.2.6.3).

2.2.6.2 Sampling Exterior Soil Gas (SGe)

Exterior soil gas samples come from boreholes advanced into the vadose zone in areas outside the footprint of a structure. Exterior soil gas samples are also useful when identifying and delineating a chlorinated solvent source via the soil gas plume, evaluating preferential pathways, vapor intrusion potential at undeveloped properties, or when a property owner will not permit installation of subslab soil gas sampling ports. While vapor samples within the backfill of preferential pathways may aid some investigations (e.g., those with irregular impact distribution), IDEM is mainly focused on vapor migration within conduits during delineation in preferential pathways. Assessing the need for a remedy due to preferential pathway vapor intrusion may also involve conduit sampling (Section 2.2.6.4).

For purposes of this document, IDEM generally considers shallow soil gas to include samples collected no more than five feet below ground surface, and deep soil gas to include samples collected at more than five feet below ground surface.

Sampling Exterior Soil Gas: Appropriate Conditions

Soil moisture content strongly affects migration of vapors through the subsurface (Tillman and Weaver, 2007). Wetting fronts moving downward through the unsaturated zone can cause underestimation of vapor concentrations. Significant precipitation may cause high vacuum readings, extended sample collection time, and visible moisture droplets within the sampling train during sample collection. If these occur during sample collection, results should be considered as a minimum value and may not be representative of typical conditions. Therefore, IDEM generally does not recommend collecting SGe samples during or immediately after a significant precipitation event [at least one inch of rain within 72 hours (ITRC, 2007b)]. The amount of precipitation required to affect the movement of vapors will depend on several factors, including soil type, soil moisture conditions prior to the precipitation, ground cover, and other factors that influence infiltration. Finer soil, for example, is generally more saturated and retains additional moisture after a precipitation event as compared to a coarser soil. Because of this, IDEM relies on the professional judgment of a qualified geologist (e.g., a Licensed Professional Geologist) to determine when sampling conditions are appropriate. Soil boring logs should note soil moisture conditions via field observations for each soil gas sampling port.

Sampling Exterior Soil Gas: Sample Number and Placement

Volatile release-related chemicals in both soil and groundwater may be a source of subsurface vapors. Sample number and placement should depend on the purpose of the soil gas samples (source determination, delineation, risk assessment, etc.) To evaluate subsurface vapors, U.S. EPA recommends soil gas surveys that include a “near-source” soil gas sample collected immediately above each potential source (U.S. EPA, 2015). Near source soil gas samples are expected to have the highest concentrations and be the worst-case indicator of vapor intrusion potential. Because source depths vary and subsurface conditions can affect vapor transport, IDEM cannot provide an exact sample collection depth. Near source soil gas samples should consider location-specific conditions including an evaluation of affected stratigraphic units, moisture conditions in those units, and whether confining units are present. For example, because moisture can impede vapor flow and affect sampling, the sample port should be set far

enough above the capillary fringe to ensure that groundwater is not present. While collection of samples from the impacted stratigraphic layer is preferred, it may be acceptable to install soil gas probes into adjacent units if vapor flow between the units is expected to be similar. IDEM also cannot recommend specific horizontal spacings between sample points as they are location specific. Horizontal soil gas spacing should consider historical use, subsurface lithology, and how lithology affects vapor flow. At larger industrial facilities where source areas are unknown, it may be appropriate to set initial soil gas sample points on 100 by 100-foot grid. At releases where source areas are known, a more focused, biased sampling array of 20 feet by 20 feet may be preferred.

If a source is much deeper than a potential receptor, it may be appropriate to collect stratified soil gas samples to evaluate vertical attenuation of vapors through the soil column. U.S. EPA (2015) recommends that soil gas samples be collected from multiple locations and depth intervals between the vapor source and potential receptors. When collecting stratified/nested soil gas samples, one sample should be collected closest to the source(s) and one sample should be collected close to the potential receptor, either at the depth of the building's foundation or its basement, if evaluating future exposure potential.

In some instances, deep soil gas samples are unrealistic due to shallow groundwater. When this happens, collect shallow soil gas samples. Because soil gas concentrations can exhibit considerable spatial variability due to atmospheric influence, precipitation, advective flow, etc., additional sampling events or locations may be appropriate to ensure representative values. If shallow groundwater does not allow for soil gas probe installation, IDEM will typically expect vapor intrusion investigations at occupied structures if those structures are within 100 feet of a potential soil source of vapors, or underlain by or in contact with groundwater exceeding IDEM's published groundwater levels for VOCs, unless convincing lines of evidence indicate otherwise. In some cases, additional monitoring wells may be necessary to determine whether VOC plumes in groundwater extend under structures.

Soil gas concentrations tend to be higher beneath a building than at the same depth in adjacent open areas when the vapor source is underneath the building, even if the source is laterally extensive relative to the building footprint (U.S. EPA, 2015). When SGe is used to estimate subslab concentrations (e.g., when evaluating potential vapor intrusion risk in areas where there are as yet no buildings or where access has not been granted), submit lines of evidence indicating that SGe sample results are representative of what would be under the slab. SGe samples should be collected from depths below the building's foundation and along the side of the building closest to the source as a reasonable worst-case representation of conditions underneath the building in the absence of routes for preferential vapor migration or soil gas entry.

Active Soil Gas Sampling Procedures

1. Advance a borehole. Exterior soil gas sampling requires a borehole, advanced using a hand auger, a hollow-stem auger, or direct-push methods. Small-diameter (less than two inches) boreholes, installed using direct-push methods, minimize disturbance of surrounding soil. Placement of exterior soil gas samples depends on the purpose of the sampling. When delineating soil gas plumes, placement should be governed by the needs associated with that task – typically, stepping out from a known or suspected source. When evaluating the potential for soil gas to enter a nearby structure, it is generally preferable to place the borehole as close as possible to the structure.

Unless professional judgment suggests otherwise, collect SGe samples from two locations near residential buildings, along the side of the building closest to any known vapor source. For large commercial buildings, two or more SGe samples per side of the building may be necessary to characterize vapor conditions in the subsurface, and additional SGe sampling locations may be necessary along multiple sides of the building.

All else equal, soil gas samples collected from a depth just above a known or suspected vapor source are considered more closely associated with worst-case conditions for purposes of predicting the potential of vapors to enter structures compared to shallow gas samples (U.S. EPA, 2015). As with groundwater, local geology, preferential pathways, and chemical characteristics will often have a considerable influence on subsurface transport and must be considered when choosing sampling locations.

2. Install a vapor sampling probe and seal the sampling port. To avoid cross-contamination of vapor samples by the sampling equipment, use vapor probes made of inert materials (e.g., stainless steel, Teflon®, Nylon®, polyethylene, etc.) that are appropriate to sample the release-related chemicals (U.S. EPA, 2015; Ohio EPA, 2020; Schumacher et al., 2016). Where practical, use permanent sample ports, as this allows repeated testing of vapors from the same location. Permanent sampling port materials should be durable enough to last through multiple sampling events. Minimize the number of fittings and tighten them as necessary to avoid system leaks. To prevent ambient air from entering the sampling train, seal the annulus between the probe and the borehole.
3. Allow the subsurface to equilibrate. U.S. EPA (2015) notes that installing soil gas probes can disturb subsurface soil conditions and recommends allowing the subsurface to equilibrate prior to sample collection. Appropriate equilibration times depend on installation technique. IDEM recommends sampling at least 24 hours after a permanent probe has been installed. Based on project objectives, temporary probes may be installed and sampled as soon as two hours after installation.
4. Perform a leak test. All connections or fittings in the sampling equipment need to be tight, so that outside air leakage into the sample collection container does not occur. For this reason, perform a leak test to check the integrity of the sampling system. Common tracers used during leak checks include helium, propane, isopropanol, pentane, and butane. Choose a tracer that will not interfere with the analytical method for the sample. IDEM recommends leak testing prior to each sampling event, but if previous leak test results or local geologic conditions provide a strong line of evidence that leak checks are not necessary for each sampling event, IDEM will consider that evidence. The water dam method of leak detection is acceptable for subslab port sampling. See Hartman (2006), NYDoH (2006) and Cal EPA (2015) and U.S. EPA (2020) for detailed guidance on leak testing.
5. Purge the sampling apparatus dead volume. Purge three times the dead volume of the sampling apparatus. A large, graduated syringe or hand-operated vacuum pump are suitable for this purpose. The dead volume of the sampling apparatus includes the implant screen and the tubing, but not the sample container volume nor the sand pack volume. Avoid over-purging. Minimal purging reduces the risk of inducing air flow from outside the area of interest. Sampling equipment with the smallest possible internal volume that can meet project DQOs will reduce the necessary purge volume.
6. Collect the vapor sample. Vacuum during sampling should be as low as possible, subject to acceptable leak test results. Low vacuum and a low sample collection rate will minimize short-circuiting of vapors from outside the area of interest. A sampling rate of 100 to 200 milliliters per minute is preferable (Cal EPA, 2015). A very slow draw rate will improve results where wet or fine-grained soil necessitates high vacuum.

Passive Soil Gas Sampling

Passive soil gas sampling procedures are similar to those used to collect active soil gas samples. Passive sampling relies on the diffusion of chemicals in the vapor state to sorbent(s) housed in a chemically inert container designed to protect sample integrity (Hodny et al., 2009). For passive soil vapor sampling, a

hole must be drilled, the sampling device should be protected from direct contact with soil, and the sampling device should be sealed in place with a seal that is at a depth just above the sampling device, and capped at the ground surface (McAlary et al., 2014a, 2014b, 2014c; Hodny et al., 2009; Odencrantz and O'Neill, 2009). For soil gas sampling, it may not be necessary to purge when using passive samplers (McAlary, 2014). After several days, chemical vapors amass onto the sorbent material. The sampling device is then removed and analyzed.

Possible advantages of passive sampling include longer-term sample collection periods, lower costs, and simpler procedures. Possible problems include poor retention of target chemicals, starvation effects, matching target chemicals with appropriate sorbents, and unplanned uptake of non-target chemicals. McAlary et al. (2014a, 2014b, 2014c) have determined that passive samplers can be used to quantify soil vapor concentrations provided the uptake rate of the sampling device is less than the supply rate of vapors from the surrounding materials. This avoids low bias from the starvation effect.

Dawson et al. (2015) provides an overview of different passive samplers and factors to consider when selecting an appropriate passive sampling device. For soil gas sampling, passive permeation sampling devices may be particularly suited to soil vapor sampling as the hydrophobic nature of the membrane limits soil moisture uptake. IDEM recommends consulting your analytical laboratory for the latest information on passive sampling technology, uptake rates, sorbents, sampling protocols, and necessary quality assurance procedures.

2.2.6.3 Sampling Subslab Soil Gas (SGss)

SGss sampling means collection of air samples from immediately below the basement or slab of a building. The process involves drilling one or more holes through the floor, placing a sleeve or probe through the floor, and then collecting an air sample into an evacuated canister. SGss ports may be permanent or temporary.

IDEM considers paired SGss and indoor air samples best for evaluating vapor intrusion potential into indoor air. Paired samples allow quantification of the actual increased risk from vapor intrusion, while reducing concerns about potential background sources within the building. However, SGss sampling is acceptable as a stand-alone screening tool, provided there is an adequate investigation of preferential pathways and subslab spatial variability. In instances where subslab sampling is conducted without indoor air sampling, IDEM recommends a more structured preferential pathway investigation at each building location (e.g., one conduit vapor sample per residence within the potential preferential pathway).

Sampling Subslab Soil Gas: Appropriate Conditions

Most indoor air measurements represent a narrow “snapshot in time” because of problems with getting repeat access and uncertainty over seasonal and building variations. Due to these uncertainties and limited sampling data, IDEM recommends sampling during “worst-case” conditions. Sampling during worst-case conditions provides limited exposure data that is likely to be biased high. This bias may be considered when evaluating the need for action if indoor air sampling can be conducted at a frequency that addresses seasonal and building variability. IDEM will consider alternative SGss sampling schedules, especially where sampling needs are urgent, seasonal variation is insignificant, or where building conditions, weather conditions, or other factors suggest that worst-case conditions occur outside of the winter heating and dry summer seasons.

Collect SGss samples during at least two different time periods to account for worst-case conditions related to seasonal variability. Historically, the winter heating and summer cooling seasons have been considered the worst-case sampling scenarios for vapor intrusion because there is normally less external ventilation and HVAC systems can create a pressure differential that pulls gases up from the subsurface. One round of SGss samples should be collected during the winter heating season (approximately mid-

November through March), when the indoor temperature is typically at least ten degrees higher than the outdoor temperature. Winter heating season SGss samples should be collected with building windows and doors closed and the building heating system in operation.

A second round of SGss samples should be collected during the dry summer season. Soil moisture content and water table fluctuation may have a more significant impact on vapor intrusion than winter heating season conditions. The highest transfer rates for VOCs from groundwater to soil gas occur during falling water table conditions (McHugh and McAlary, 2009). Generally, the water table is falling during the hot, dry summer months in Indiana (typically July through mid-September). Additionally, buildings equipped with cooling systems will have the windows and doors closed.

Sampling Subslab Soil Gas: Sample Number and Placement

Investigative goals, utility locations, owner preferences, and other practical considerations will affect the number and locations of SGss samples. Monitoring points should be installed at locations with minimal potential for ambient air infiltration via floor penetration (e.g., cracks, floor drains, utility perforations, sumps, etc.)

U.S. EPA (2015) recommends collecting at least three SGss samples at structures with a footprint less than 1,500 square feet. However, IDEM recognizes that this may be impractical or unobtainable in residential structures. Generally, IDEM recommends collecting at least one preferentially located [i.e., close to known source(s)] SGss sample under residential structures. Additional SGss sample locations may be necessary pending evaluation of the building structure and data collected. IDEM will rely on these building evaluations and professional judgment to determine if additional SGss sample locations are necessary.

For commercial buildings IDEM recommends collecting an adequate number of SGss samples to evaluate spatial distribution of vapors. Multiple SGss ports can help interpret anomalous SGss/indoor air data or support conclusions about surrounding buildings that are not well-sampled. Sampling locations should consider areas highly susceptible to releases (e.g., machine pits, dry cleaning machine locations, etc.), internal building partitions, HVAC layout, chemical distribution, utility conduits, and openings for preferential soil gas entry.

For both residential and commercial buildings, centrally located sampling ports are appropriate where the subsurface vapor source is laterally extensive relative to the building footprint (e.g., a groundwater source). Other approaches may be necessary for atypical situations, which include:

- Buildings that are very large or small
- Buildings with more than one foundation floor type
- Subsurface structures
- Conditions that might facilitate or mitigate vapor intrusion
- Multi-use buildings with distinct segmented areas that differ significantly by occupying population or exposure frequency

Sampling Subslab Soil Gas: Sampling Frequency and Duration

Assessing the risk posed from the vapor intrusion pathway through the subslab of a building generally requires at least two rounds of SGss sampling (one during the winter heating season and one during the dry summer season). Collect the second round of SGss samples from the same locations as the first. The second sampling event is especially important when confirming SGss results used as a stand-alone determination of the vapor intrusion pathway. If the results of the first two SGss sampling events are contradictory, additional sampling may be needed.

To minimize air infiltration, maximum flow rates through the SGss probe and related tubing should not exceed 200 mL/min during purging and sampling. Most subslab samples are collected as grab samples, though canister fill rates and durations may vary depending on project objectives.

Sampling Subslab Soil Gas: Recommended Procedures

Subslab soil gas sampling is similar to exterior soil gas sampling (Section 2.2.6.2), though there are some key differences. U.S. EPA (2015) describes a procedure for collecting subslab soil gas grab samples in six-liter evacuated canisters. IDEM has determined that the Vapor Pin® or similar subslab soil gas sampling technology is acceptable, as are canisters as small as one liter, if they meet project DQOs. When collecting subslab soil gas samples:

- Operate heating systems during colder months to maintain normal temperatures of at least 65°F for at least 24 hours prior to and during sampling
- Perform a leak test prior to each sampling event
- Purge three volumes of the sample probe and tubing immediately prior to sampling
- Use a large, graduated syringe or hand-operated vacuum pump to purge the sampling point
- Avoid exceeding a maximum flow rate of 200 mL/min during purging and sampling to minimize air infiltration.

When subslab soil gas sampling is no longer needed at a building, remove the sampling ports and seal the remaining holes to prevent migration of vapors through the slab.

2.2.6.4 Sampling Conduit Vapor

Sewers and other open conduits can receive, intercept, and transmit vapors or liquids containing volatile chemicals to receptors. While there are differences between conduits (within an open pipe) and utility corridors (backfill around underground utilities), IDEM considers both to be anthropogenic preferential pathways. As multiple studies note, there is increasing recognition of the importance of conduits as a pathway for vapor intrusion, as vapors can migrate into occupied structures through plumbing systems that are not properly maintained (Roghani et al., 2017; Pennell et al., 2013; Guo et al., 2015; McHugh and Beckley, 2018). In the text below, the term *chemicals* refers specifically to vapor forming chemicals.

Sampling Conduit Vapor: Appropriate Conditions

Collect conduit vapor samples quarterly over the course of a year. When collecting conduit vapor samples via grab techniques, collect those samples when baseline flow is relatively low – typically, between 9 AM and 3 PM for sanitary sewers (McHugh and Beckley, 2018). When investigating conduits that may be affected by precipitation, wait at least 72 hours following a significant rain event (defined for this purpose as being at least one inch) before collecting conduit vapor samples. These rain events should be considered for all conduits that could be significantly impacted by surface infiltration.

While conduit vapor samples are generally preferable, liquid samples collected from within the conduit may provide information about vapor sources. To reduce the influence of ambient air, collect conduit vapor samples prior to collecting conduit liquid samples. If possible, collect liquid samples when the water table is above the conduit. This allows for potential infiltration of release-related chemicals into the conduit.

Sampling Conduit Vapor: Number and Placement

Collect conduit vapor and/or liquid samples from those conduits most likely to have the highest concentrations of release-related volatile chemicals. IDEM recommends evaluating conduits when any of the following applies:

- The conduit was used for volatile chemical disposal

- Shallow groundwater that contains volatile chemicals intersects a conduit
- Indoor air exceedances persist even after indoor air sources and ordinary vapor intrusion have been ruled out

For example, if chemicals were disposed of directly down a sink or floor drain leading to the sanitary sewer, a conduit vapor sample can be collected at the closest point of access to this source [e.g., behind the u-bend (water trap) of the sink, the sewer cleanout leading from the property, or closest connected conduit access point]. However, research has shown that there may be larger variability if the sample is collected from a sewer cleanout rather than a maintenance entrance (McHugh and Beckley, 2018). If shallow groundwater containing release-related chemicals intersects a conduit, a conduit liquid sample can show whether those chemicals are infiltrating the conduit, thus functioning as a continuing source of vapor into the conduit. In this scenario, conduit vapor samples should be collected with conduit liquid samples.

Sample each conduit that meets the criteria above and that may be a preferential pathway for vapors. Additionally, collect one up-gradient and two down-gradient conduit vapor samples from each conduit (where gradient is determined by the flow direction of liquids inside the conduit). Delineation of conduit vapor should continue in the appropriate direction(s) until concentrations no longer exceed IDEM's published levels for conduit vapors or their project-specific equivalents.

Sampling Conduit Vapor: Frequency and Duration

Temporal variability in conduit vapor concentrations is relatively high (McHugh et al., 2007; Holton et al., 2013; U.S. EPA, 2015c; McHugh and Beckley, 2018), and is much higher over a timescale of months compared to a timescale of days. McHugh and Beckley (2018) show that short-term time integrated samples (24-hour evacuated canisters or 7-day passive samplers) provide little benefit compared to grab samples for estimation of long-term average vapor concentrations in a sewer. For this reason, IDEM recommends performing four quarterly sampling events to evaluate conditions over a year for chlorinated volatile chemicals. Two quarterly sampling events suffice for petroleum releases (Section 2.3.6.8).

Sampling Conduit Vapor: Recommended Procedures

The following is a brief outline of procedures for sampling conduit vapor using evacuated canisters. Procedures are similar for passive samplers, though obtaining accurate results using passive samplers requires selection of a proper sampler and sorbent combination to avoid starvation, poor retention, and poor recovery (U.S. EPA, 2014b; McHugh, et al., 2017). Passive sampler choice should consider uptake rates and moisture fluctuations within the conduit.

- Assess sewer access point types and accessibility approximately 24 hours prior to sampling, along with the approximate depth of the utility and depth of any liquid
- Cut sample tubing so that vapor samples can be collected approximately one foot above the level of any liquid
- Document appropriate sampling information for canisters and sorbent samplers, including sample identification, sampling location, sampling depth, sampling times (initial and final), weather conditions, and possibly HVAC building conditions if evaluating results paired with indoor air samples
- Record initial and final vacuum, canister type, and canister/flow controller numbers
- Attach Teflon® tubing (potentially weighted)
- Check the sampling assembly for leaks
- Open sewer access points as little as possible (closed, if feasible) to minimize ambient air influence prior to and during sampling activities

- Use appropriate screening instruments to measure concentrations of volatile organic chemicals and oxygen after opening sewer access points, and check results against lower explosive limits
- Lower tubing attached to evacuated canisters to approximately one foot above any water within the sewer
- Suspend evacuated canisters below the access point if sampling time exceeds five minutes
- Submit samples to the laboratory within holding times

2.2.6.5 Sampling Crawl Space Air

SGss samples are not an option in buildings constructed over a crawl space. Such buildings will require collection of SGe or crawl space air samples, preferably in conjunction with indoor air samples and/or SGss samples (if there is a partial basement or slab). However, crawl space air samples may suffice in certain situations as a stand-alone method for investigating vapor intrusion.

Sampling Crawl Space Air: Appropriate Conditions

Crawl space air samples should be collected during at least two different time periods to account for seasonal variability. Samples should be collected under the worst-case conditions and time periods described in Section 2.2.6.3. Although a standard timeframe is not noted in other guidance, closing crawl space vents 24 hours prior to the sampling event is reasonable. IDEM will consider alternative sampling schedules, especially where sampling needs are urgent, seasonal variation is insignificant, or where building conditions, weather conditions, or other factors suggest that worst-case conditions occur outside of the winter heating and dry summer seasons.

Sampling Crawl Space Air: Number and Placement

One centrally located crawl space air sampling point is typically sufficient for most residential buildings. Crawl spaces are rare in commercial buildings. Such structures will require a project-specific sampling plan that includes enough samples to adequately characterize crawl space air concentrations. Placement of samples should take into consideration the likely location of the highest subsurface vapor concentrations.

Concurrent ambient air and crawl space air sampling may help sort out sources if activities near the structure under investigation may be affecting crawl space air concentrations. Any such ambient air concentrations should be used as a qualitative line of evidence, and not directly subtracted from the measured crawl space air concentrations.

Sampling Crawl Space Air: Frequency and Duration

Assessing the risk posed from the vapor intrusion pathway within a building over a crawl space requires collection of at least two sets of crawl space air samples, with the second set of samples collected from the same locations as the first. Additional sampling may be necessary if the results of the first two sampling events are contradictory.

IDEM recommends collecting crawl space air samples over a 24-hour period in residential buildings. The sample duration for commercial decision units should capture normal working conditions. For example, if shifts are a twelve-hour period, then the samples should be collected for a twelve-hour period. Alternatively, if multiple shifts occur it may be necessary to collect one 24-hour sample or two eight-hour samples. Project objectives may dictate alternative canister fill rates.

Crawl spaces used for storage purposes may contain volatile chemical sources that could complicate vapor intrusion evaluations. See Section 2.2.6.6 for potentially applicable information on indoor air background sources.

2.2.6.6 Sampling Indoor Air

Acceptable indoor air sampling procedures are described in U.S. EPA (2019g). Additional information regarding indoor air sampling appears in U.S. EPA (2015) and ITRC (2007b). Analytical laboratories can also provide guidance. Note that it can be difficult to interpret indoor air sample results in the absence of vapor sample results from outside the structure.

Sampling Indoor Air: Appropriate Conditions

IDEM has determined that indoor air samples should be collected during at least two different seasons that provide the best opportunities to capture worst-case conditions. Historically, the winter heating and summer cooling seasons have been considered the worst-case sampling scenarios for vapor intrusion. This is because windows and doors are typically closed during the heating and cooling seasons, and HVAC systems can create a pressure differential that draws vapors up from the subsurface. Project-specific vapor sampling plans should account for HVAC layout and operating conditions during time of sampling. If the project-specific vapor sampling plan will be used for multiple sampling events, the indoor air building checklist should reference the sampling plan and note any changes in HVAC conditions between sampling events. In addition, falling water table conditions that commonly prevail in the summer can expose source material.

Therefore, unless there is an immediate need to characterize indoor air and current human exposures, or evidence shows that seasonal variation in indoor air concentrations is not significant:

- Collect one round of indoor air samples during the winter heating season when building windows and doors are closed and the building heating system is in operation (when the indoor air temperature is consistently at least ten degrees higher than the outdoor temperature)
- Collect one round of indoor air samples during the summer cooling season when building windows and doors are closed and the building cooling system is in operation

Differential pressure measurements are a valid line of evidence when evaluating vapor intrusion that is unrelated to sewer or other conduit transport. The difference in pressure between the indoor air and SGss provides a primary advective force for vapor intrusion. Vapor intrusion is likely when the pressure inside a building is lower than the pressure in soil gas below the building. If the pressure inside is positive compared to the subslab, there should be little or no vapor intrusion potential. Pressure differential measurements over hours, days, or weeks using small diameter subslab sampling ports or pressure taps can be used as a line of evidence to demonstrate whether conditions conducive to vapor intrusion exist during a sampling event. Aspects of building pressure dynamics, including information regarding HVAC use during sampling events should be documented⁶.

To minimize the impact of indoor background sources on indoor air sampling, building occupants should suspend (where practical) activities such as smoking, dry cleaning, painting, mowing, pesticide application, and the use of sprays, cleaners, solvents, etc. prior to sampling. Document exceptions observed during sampling. IDEM (2021b) contains guidance that may prove useful when looking for potential indoor background sources of release-related chemicals. Interviewing building occupants may reveal potential indoor background sources. If feasible, identify and remove potential background sources prior to sampling. U.S. EPA (2011b) contains discussions of background levels.

Sampling Indoor Air: Number and Placement

For residential buildings, worst-case indoor air samples are generally located in the basement or area where vapors first enter the building. Generally, IDEM recommends at least three 24-hour samples: one

⁶ See IDEM (2021b) for more on this topic.

indoor air sample in the basement or assumed worst-case location, one indoor air sample in the general living area, and one ambient air sample. If the building has multiple levels, IDEM recommends one indoor air sample from each floor. Place evacuated canisters within the breathing zone (three to five feet above the floor) and collect the ambient air sample upwind of the building.

Project-specific vapor sampling plans should account for atypical situations, which include: (1) very large homes or buildings; (2) multi-use buildings, particularly ones with segmented areas that are occupied by different populations (e.g., day care within office) or have different occupancy patterns over time. Additional samples may also be warranted, depending on internal building partitions, HVAC layout, chemical distribution in the subsurface, and occurrence of observable locations of potential soil gas entry (e.g., basement sumps or drains, relatively large holes or spaces in the foundation floor, entry points for utilities). Closed rooms located below ground may have significantly higher concentrations originating from vapor intrusion. Closed rooms may warrant sampling to characterize reasonable maximum exposure levels, if occupied, or to diagnose vapor intrusion, even if not occupied.

When planning indoor air sample locations in commercial buildings, consider the following:

- Individual offices within a building
- Individual retail spaces within a larger commercial complex
- Areas operating under separate HVAC systems
- Areas with higher exposure potential (where occupants spend most of their time)
- Areas above the highest subsurface chemical concentrations
- Areas with utility inlets

Sampling Indoor Air: Frequency and Duration

Assessing risk posed from the vapor intrusion pathway requires collection of at least two rounds of indoor air samples. To minimize variability between indoor air samples collected over time, collect the second round of indoor air samples from the same locations as the first. Pairing indoor air samples with subslab soil gas samples can help assess indoor air background issues. If the results of the first two sampling events are contradictory or inconclusive, additional samples may be needed.

IDEM recommends completing indoor air sample collection over a 24-hour period for current (or when evaluating future) residential use, and an 8-hour period for commercial use. Alternative canister fill rates are possible depending on project objectives. However, the fill rate must be established prior to obtaining canisters from the laboratory, since the pre-set flow regulators for the canisters are typically supplied by the laboratory. All else equal, a longer collection period for each individual sample would be expected to yield a more reliable basis for estimating long-term, time-averaged exposure than would a one-day sample collection period.

2.2.6.7 Ambient Air Sampling

Concurrent ambient air and indoor air sampling may help sort out sources if activities near the structure under investigation may be affecting indoor air concentrations. U.S. EPA generally recommends beginning ambient air sampling at least one hour, but preferably two hours, before indoor air monitoring begins (U.S. EPA, 2015). U.S. EPA recommends this practice because most residential buildings have an hourly air exchange rate in the range of 0.25 to 1.0, causing air that enters the building before indoor air sampling to remain in the building for a long time. Measured ambient air sample concentrations should be used as a qualitative line of evidence. Ambient air sample concentrations should not be directly subtracted from the measured indoor air concentrations.

2.2.6.8 Background Indoor Air Sources

Ambient and indoor chemical sources may complicate interpretation of indoor air sample results. Many VOCs common to environmental investigations are present in tobacco smoke, cleaning supplies, craft and hobby supplies, stored fuels, and other common household products, and may exceed published levels for chemicals such as benzene, carbon tetrachloride, chloroform, methylene chloride, trichloroethene, and tetrachloroethene. For this reason, it is important to assess background indoor air sources and concentrations at a decision unit when evaluating the vapor intrusion to indoor air pathway.

Lines of evidence useful when determining whether indoor air chemicals are attributable to background sources or chemicals in the subsurface include:

- Factors listed in IDEM (2021b)
- Ambient air sample results
- Concentration gradients within a building
- Subslab soil gas (SGss) to indoor air concentration ratios
- Individual chemical concentration ratios across media
- Presence of indicator chemicals
- Use of radon as a tracer gas to determine a structure-specific attenuation factor

If an indoor source is suspected, conduct a detailed inspection of the building's contents and survey occupant activities. Identify the presence of common household items (e.g., cleaning supplies, craft and hobby supplies, and fuels) that contain VOCs common to the release, as well as recent activities such as dry cleaning, or home improvements (e.g., painting or new carpet) that may contribute to exposures. See IDEM (2021b) for an example of a building survey.

Comparing SGss, ambient air and indoor air results to each other may reveal the relative contribution of vapor intrusion and background sources to indoor air concentrations. In this case, time-integrated sampling methods are recommended for indoor air, because concentrations of vapor-forming chemicals can vary significantly over time.

2.2.7 Sample Handling

Some samples require physical and/or chemical preservation in order to maintain sample integrity from time of collection until delivery to the laboratory. Laboratories can provide information on appropriate sample preservation methods. Alternatively, U.S. EPA (2019d) contains summary tables showing preservation methods and holding times for SW-846 analytical methods. It is important to deliver samples to the laboratory as soon as possible after collection or within a set time frame if the method requires it (U.S. EPA, 2019d). Samplers must maintain and document custody of the samples from collection until shipment or delivery to the laboratory.

2.2.8 Sample Analysis

It is important to choose analytical methods that can meet project DQOs. The QAPP, SAP, or other relevant project-specific sampling document should list sample analysis methods and any deviations from those methods. Reference to standard published methods is typically acceptable if the laboratory performs the analysis exactly as stated in the method. Sources for standard analytical methods include U.S. EPA (2019, 2019b, 2019c, 2019d). When analyzing solid samples (e.g., soil, sediment, and solid waste) for VOCs, IDEM recommends collecting and extracting them using U.S. EPA SW-846 Method 5035A. IDEM (2021a) contains additional guidance on this topic.

Key considerations regarding sample analysis include:

- Can the analytical methods deliver reporting limits at least as low as relevant remediation objectives?
- Can the laboratory provide data that meets project DQOs?⁷

2.2.9 Data Reporting

Documentation needed to evaluate data will depend on the intended use(s) of the data. A quality assurance/quality control (QA/QC) program is the means of judging whether the data meets DQOs. QA/QC programs use information from sampling, laboratory operations, and method-specific procedures to make this decision.

Table 2-B lists elements that IDEM has determined are essential to support three levels of QA/QC. Level II elements [which IDEM calls minimum data documentation recommendations (MDDRs)] are appropriate to support investigations where data validation is not necessary. IDEM programs to which this guidance applies (Section 1.1) will not typically require submission of Level III or Level IV elements listed in Table 2-B, but may do so on a project-specific basis. If data validation is required, IDEM requests submittal of Level III QA/QC elements unless the program requires submittal of Level IV QA/QC elements. Analytical results submitted to IDEM's Office of Land Quality (OLQ) should, and where required by OLQ programs must, meet the IDEM/OLQ [Electronic Data File Submittal Guidelines](#).

Sampling documentation is an important component of demonstrating that sample results meet project DQOs. IDEM's Office of Land Quality does not typically require specific field documentation forms. In addition to the appropriate elements in Table 2-B, the following sampling-related documentation should support every investigation:

- Completed chain of custody with sample date, time, and identification
- Map or diagram of sample locations
- Sample field sheets that document sample identifiers, locations, date and time, sampling methods and equipment, samplers, calibration methods, and any notable observations (color, clarity, texture, reactions with preservatives, etc.)
- Blanks – trip, field, or equipment rinsate blanks, as appropriate
- Identity of field duplicates – typically at least one per twenty samples per matrix for each method

IDEM (2021a) provides a template for recording information on various vapor intrusion investigations. Vapor investigation sampling documentation should include, where appropriate:

- Certification of evacuated canister cleanliness (batch or individual)
- Leak test procedures and results
- Purge volume
- Field records of initial and final canister pressures, start and stop canister fill times, and fill rate

The following laboratory-related items should support every investigation:

- Completed chain of custody with date and time of receipt
- Condition of samples on receipt
- Sample identification – project identification and lab identification
- Sample preparation logs with extraction, cleanup, or digestion details
- Certificates of analysis with method, analysis date, results and associated qualifiers, method detection limits, reporting limits, and any dilution factors
- Case narrative detailing any deviations, problems, and corrective actions

⁷ Note that Indiana does not currently certify laboratories for remediation work.

Table 2-B: Data Deliverables

Element	Method Type	Level		
		II	III	IV
Case Narrative	All	✓	✓	✓
Sample introduction method (e.g., direct injection, purge-and-trap)	Chromatography methods	✓	✓	✓
Tuning criteria and results	Gas and liquid chromatography/mass spectroscopy (GC/MS & LC/MS)		✓	✓
Initial calibration and verification	All		✓	✓
Continuing calibration(s)	All		✓	✓
Method Blank	All	✓	✓	✓
Laboratory control sample	All	✓	✓	✓
Internal standard summary	GC/MS, LC/MS, GC		✓	✓
Surrogate recoveries	GC/MS, LC/MS, GC	✓	✓	✓
Matrix spike/matrix spike duplicate recoveries	All (except TO-14A, TO-15, TO-15 SIM, and TO-17)	✓	✓	✓
Interference check sample	Inductively coupled plasma methods		✓	✓
Serial dilutions	Inductively coupled plasma methods		✓	✓
Method of standard additions (if applicable)	Inductively coupled plasma methods		✓	✓
Raw data (instrument printouts, chromatograms, and/or mass spectra as applicable)	All			✓
Confirmation on second column (or GC/MS)	Pesticides, polychlorinated biphenyls, and organic chemicals by GC		✓	✓

2.2.10 Data Evaluation

The data evaluation process assesses whether the sample results meet project objectives. The process has three major components: verification, validation, and comparison against user requirements. The process verifies that sample collection, documentation, and delivery occurred as planned. If necessary, the results are validated against predetermined quality criteria. Analytical results are then compared against user requirements.

The usability of any data set is based on assessing sampling and laboratory activities. This assessment is based on the evaluation of data quality indicators: precision, accuracy (as bias), representativeness, comparability, completeness, and sensitivity.

2.2.11 How IDEM Will Evaluate Nature Determinations

IDEM evaluation of nature determinations will include consideration of the following:

- Appropriate field screening methods used
- Sampling procedures appropriate for the release-related chemicals and/or per SAP
- Samples handled appropriately
- Appropriate release-related chemicals, given release/facility history
- Appropriate analytical methods used
- Holding times met
- Reporting/detection limits at least as low as relevant delineation or remediation objectives
- Cooler temperatures acceptable on laboratory arrival
- Laboratory sample condition noted on receipt form
- Analytical data meets MDDRs (or larger element list if necessary)
- Case narrative submitted
- Surrogate recoveries within lab control limits
- Method blank results submitted
- Laboratory control sample results submitted
- Matrix spike/matrix spike duplicate recoveries within acceptable ranges: 20% relative percent difference for aqueous media, 40% relative percent difference for soil
- Field duplicates in agreement: 20% relative percent difference for aqueous media, 40% relative percent difference for soil
- Summary tables correspond with certificates of analysis
- Data on exhibits/figures correspond with certificates of analysis
- Is data validation (submission of full QA/QC) needed

2.3 Task Three: Determine Extents of Release-related Chemicals

Extents is the boundary of the volume of a medium containing one or more release-related chemicals that exceed unconditional remediation objectives⁸, and may therefore limit a property's use. Extents are most often determined for chemicals in soil, groundwater, and vapor, but may be relevant for sediment and surface water. For releases that involve more than one chemical, the extents of individual chemicals are likely to differ from each other. In such cases, the extent in a medium is the union of all the individual extents in that medium. While IDEM recognizes that non-aqueous phase liquids (NAPL) may be a risk driver or subject to other regulations, for purposes of this document it is assumed that NAPL delineation will be bounded by delineation in other media.

2.3.1 Basis for Requirement

[IC 13-12-3-2](#) and [IC 13-25-5-8.5\(c\)](#) require adequate characterization of the nature and extent of release-related chemicals. The present and likely future extents of release-related chemicals define the boundaries of the volumes of media where one or more remedy decisions are necessary under [IC 13-25-5-8.5\(c\)](#). Remedies may be necessary to control risks associated with soil exposure, plumes of release-related chemicals in groundwater, leaching of release-related chemicals from soil to groundwater, or vapors arising from volatile release-related chemicals in soil, NAPL, or groundwater that enter or have the potential to enter occupied structures. For these reasons, an understanding of the present and likely future extents of release-related chemicals is necessary to protect human health and the environment.

IDEM will not require a determination of likely future extents under every conceivable circumstance. Determinations should focus on scenarios that are *reasonably* likely to occur. Where there is disagreement about what is reasonable, responsible parties must submit lines of evidence in support of their position. IDEM will consider those lines of evidence on their merits, using professional judgment and knowledge of the circumstances specific to the release.

Sometimes determining extents is impractical or unnecessary. Proposals to forego or limit extents determinations must be supported by lines of evidence provided by the responsible party. Applicable lines of evidence are necessarily project-specific but may include:

- Distance and/or time of travel from known extents to existing or potential receptors including, where applicable, sensitive receptors (e.g., schools, daycare facilities, wellhead protection areas, ecologically important habitats, etc.)
- Characteristics of release-related chemicals (e.g., mobility, toxicity, volatility, persistence)
- Current and likely future use of the property, including groundwater use and the presence of structures susceptible to vapor intrusion
- Magnitude of release-related chemical concentrations relative to unconditional remediation objectives
- Extent of the area in which the release(s) occurred
- Underground utilities or other preferential pathways that may affect chemical migration
- Possible aquitard influences
- Potential for changes in groundwater or vapor flow direction and pressure gradient (e.g., start up or shut down of existing or planned production wells, construction of utility corridors, basements, fill areas, etc.)

IDEM will evaluate proposals to forego or limit extents determinations on their merits.

⁸ Defined in Section 3.3

2.3.2 Present Extents: Soil

Soil is the unconsolidated mineral or organic material lying between the ground surface and unaltered parent material below. This guidance does not define specific depth intervals as comprising either surface soil or subsurface soil. However, consistent with U.S. EPA (2002d, page 2-7), IDEM's published levels for soil are applicable to soil where current or future soil exposure is likely. Depths are typically shallow but also consider soil that may be brought to the surface in the future.

2.3.2.1 When is a Present Extents Determination Necessary in Soil?

A present extents determination for release-related chemicals in soil is necessary for most of the releases addressed by IDEM's Office of Land Quality. The principal exceptions are releases to surface water addressed by OLQ's Emergency Response Section under the Spill Rule⁹ and instances in which adequate initial soil sampling does not reveal concentrations of release-related chemicals exceeding unconditional remediation objectives.

2.3.2.2 Determining Present Extents in Soil

This subsection describes some acceptable procedures for determining present extents of release-related chemicals in soil. IDEM will evaluate other approaches on their merits. Unless compelling lines of evidence show otherwise, present extents determinations are required in both the horizontal and vertical dimensions. If a remedy has already reduced concentrations of release-related chemicals and it is necessary to determine whether additional remedies are required, see Section 3.

Horizontal Extent Determination Beginning at or Near a Source Point

Horizontal extent determinations that begin at or near a source point are sometimes referred to as step out procedures. When selecting sample points for the step-out procedure, start at locations where release-related chemical concentrations are likely to be highest. Factors to consider when selecting sample locations include:

- Known release points
- Vertical location of highest concentrations (surficial, buried, under a barrier)
- Phase (soil, NAPL, mixture)
- Release-related chemical solubility and volatility

If soil samples collected in locations most likely to have the highest concentrations are below unconditional remediation objectives, determination of extents in soil is not necessary. Conversely, if soil concentrations of release-related chemicals exceed unconditional remediation objectives, step out until present extents are determined. IDEM's residential soil levels, naturally occurring background levels, and site-specific residential levels are all acceptable unconditional remediation objectives. Ecological risk evaluations may require different delineation criteria. For chemicals without IDEM published residential soil levels (e.g., some volatile chemicals), delineate to IDEM's published excavation worker levels. If migration to groundwater is a concern, delineate until soil leaching test results are acceptable.¹⁰

Horizontal Extent Determination Beginning at or Near a Potential Receptor

Horizontal extent determinations that begin at or near a receptor and proceed toward a source point are sometimes referred to as the step-in approach. The step-in approach may be preferable when there is

⁹ [327 IAC 2-6.1](#)

¹⁰ Though not necessary for delineation, additional soil samples may be necessary for remedy design.

concern that unacceptable exposures are already occurring. If unacceptable exposures are occurring, the step-in approach may allow those exposures to be identified and controlled earlier.

The step-in approach should not stop once soil extents based on unconditional remediation objectives are determined. It will be necessary to continue at least until excavation worker levels are delineated.¹¹ In some cases, continuing until the source point is reached may be necessary for evaluation of leaching potential and/or remedy design. For volatile release-related chemicals, continuing the step-in process until the source point is reached allows focus of soil gas screening efforts.

Vertical Extent Determination

Vertical extent determinations for surficial releases to soil typically begin with soil sampling at the ground surface and proceed downward until the potential for soil exposure is adequately understood. This may involve collecting more than one surface or near surface sample. If chemicals were released directly into the subsurface or have leached or otherwise moved into the subsurface over time, subsurface samples will usually be necessary to understand the potential for soil exposure. Sampling below 15 feet to evaluate soil exposure risk isn't generally necessary unless exposure to soil below that depth is likely to occur (e.g., as the result of excavation or movement of soil). However, sampling deeper than 15 feet below ground surface may be necessary to inform remedy design, understand a soil source that is affecting groundwater or vapor, understand vertical migration of DNAPL, or for other reasons. Soil with exposure potential should be sampled regardless of its moisture content. Even saturated soil can contribute to soil exposure, particularly if it is brought to the surface and left there.

Interpolation and Extrapolation

IDEM has determined that approximate extents determinations are usually acceptable. Soil sample results that fall within a range reasonably close to unconditional remediation objectives will suffice. If soil concentration data displays a discernable spatial trend, it is often appropriate to extrapolate or interpolate soil sample results when drawing unconditional remediation objective isoconcentration lines, or isoconcentration lines for other relevant remediation objectives. Specify methods used and any identified error estimates.

2.3.3 Likely Future Extents: Soil

Although significant increases in the extents of release-related chemicals in soil are relatively unusual, responsible parties must consider the possibility that this can occur. Where an increase in soil extents is *reasonably* likely, responsible parties must provide an estimate of the likely future extents of release-related chemicals in soil.

¹¹ IDEM's published levels tables do not include residential, commercial, or recreational soil levels for volatile chemicals, defined for this purpose as having a vapor pressure equal to or greater than one millimeter of mercury.

2.3.3.1 When is a Likely Future Extents Estimation Necessary in Soil?

IDEM has identified some scenarios that require consideration of the possibility that the extents of release-related chemicals in soil will increase:

- When soil containing release-related chemicals is exposed to the action of wind or surface water
- When soil containing release-related chemicals is subject to movement via excavation or similar activities

Further discussion of each of these scenarios follows.

2.3.3.2 Determining Future Extents in Soil

Soil Exposed to the Action of Wind or Surface Water

Release-related chemicals bound to soil particles may move under the influence of wind or surface water. Movement under the influence of wind is most likely with exposed, dry, fine soil particles. Vehicular traffic, areas where vegetation is sparse because of release-related chemicals or other factors, and even pedestrians creating bare soil paths may expose soil and promote wind borne transport. Signs that this is occurring include visible dust, depositional areas, or dust complaints. Predicting future extents is difficult as wind direction and speed vary considerably in most places. An interim remedy may be necessary prior to full characterization and risk assessment.

Movement under the influence of surface water is most likely with exposed, sloping soil. It may also occur on steeply sloping soil, even when that soil is mostly vegetated. Surface water and erosion can transport release-related chemicals as sediment. Signs that this is occurring might include rills, gullies, sediment deposits, or cloudy surface water bodies during and after precipitation.

Likely future extents under the influence of surface water may be more predictable than with wind erosion, as surface water flows downhill and often follows a discernable path, either until it is absorbed into the soil column or discharges into a surface water body. As with wind erosion, interim remedies may be necessary prior to full characterization and risk assessment.

Soil Subject to Movement by Excavation or Similar Activities

Excavation and similar activities move and expose soil, and with it any chemicals in that soil. It is rarely possible to determine in advance when, whether, where, and to what depth soil excavation may occur. However, IDEM publishes soil levels for excavation worker and several other soil exposure scenarios, and those levels combined with adequate characterization of soil affected by a release may be useful when evaluating the potential need for a soil exposure remedy.

2.3.4 Present Extents: Groundwater

Groundwater is water beneath the ground surface. The present extents of release-related chemicals in groundwater is the boundary of the volume of groundwater in which concentrations of, or risks associated with, one or more release-related chemicals exceed their unconditional remediation objectives.

2.3.4.1 When is Present Extents Delineation Necessary in Groundwater?

IDEM will typically require groundwater sampling whenever a release is known or suspected, except for surficial releases of insoluble chemicals. When an administrative rule¹² applies to investigation of a release to groundwater, the administrative rule takes precedence over this guidance document.

¹² For example, [329 IAC 9-5-6\(b\)](#) requires installation of a minimum of three groundwater monitoring wells and collection of samples from each, if at least three wells were not installed during the initial site investigation. Other administrative rules may have other requirements.

Otherwise, collect at least three groundwater grab samples from depths appropriate for the release. The initial groundwater grab samples must be collected at or near the suspected source point, if known. If the source point is not known, then adequate coverage of the area under investigation is required. Three groundwater grab samples usually suffice for an area like a typical city lot (50 feet by 150 feet). Larger areas, or areas with heterogeneous subsurface geology, may require more than three initial groundwater grab samples.

If any groundwater grab results exceed one or more unconditional remediation objectives, extents delineation is required for the chemicals with exceedances. Otherwise, and assuming the sample locations adequately cover the area under investigation, extents delineation is not required in groundwater.

2.3.4.2 Delineating Present Extents in Groundwater

This subsection describes some acceptable procedures for delineating present extents of release-related chemicals in groundwater. IDEM will evaluate other procedures on their merits. When present extents delineations are required in groundwater, horizontal extent delineation is always required. Vertical extent delineation may or may not be required depending on the chemicals and geological characteristics in the area under investigation. For example, chemicals that are less dense than water may extend only a few feet into the water-bearing zone and can often be vertically delineated within the length of a standard well screen interval.

Sampling Technology

Grab groundwater samples collected using push probe technology are usually sufficient for extents delineation. Monitoring wells may be necessary in areas with heaving soil, deep groundwater, where turbidity issues cannot be overcome by other means, or in some cases for delineation of plumes that extend into more than one water-bearing unit. Monitoring wells are required for any purpose that requires long-term monitoring of release-related chemicals in groundwater.

Horizontal Extents Delineation

Horizontal extents delineation of release-related chemicals in groundwater requires determining the area underlain by groundwater that exceeds any unconditional remediation objectives. Unconditional groundwater remediation objectives for groundwater are most often IDEM's published groundwater levels. However, they can also be site-specific residential remediation objectives or concentrations corresponding to naturally occurring concentrations of release-related chemicals in groundwater (the latter usually for one or more of a small subset of metals).

Extents delineation need not be "exact". In other words, it is not necessary to continue advancing borings and collecting groundwater samples until observed concentrations in those samples exactly match unconditional remediation objectives. The effort need only be sufficient to allow a reasonable estimate of the extent. Interpolation, extrapolation, knowledge of concentration gradients, groundwater flow direction, distance to receptors, and distance to property boundaries may all be reasonable lines of evidence to consider when deciding whether a delineation effort is sufficient.

Vertical Extents Delineation

In general, vertical extents delineation of release-related chemicals in groundwater begins at the water table and extends downward until samples show release-related chemicals below unconditional remediation objectives. However, in some cases the base of the water-bearing unit still contains concentrations of release-related chemicals that exceed unconditional remediation objectives, and there is low permeability material below. The sole presence of low permeability units is insufficient evidence to

demonstrate vertical delineation without further investigation. See IDEM (2021b) for information about low permeability units relevant to delineation and eventual CSM development.

Delineation Reporting

IDEM has determined that agency review of extents delineations requires that delineations be depicted as lines drawn on maps, and that any software used to generate those lines be specified. ITRC (2016) describes software options applicable to transforming observed data into delineation maps.

Isoconcentration lines may be useful for complex plumes. An overall extents depiction that combines or shows the union of the extents of individual chemicals will often suffice for petroleum chemicals.

Sufficient groundwater samples are necessary to provide information about:

- Downgradient extents
- Upgradient extents
- Width and depth of the plume
- Concentration gradients within the plume

2.3.5 Likely Future Extents: Groundwater

As dissolved chemicals travel within groundwater via advection¹³, the extents of release-related chemical plumes (plume extents) change, and may reach previously unaffected receptors. Therefore, an adequate evaluation of release-related risk requires an understanding of likely future plume extents. This subsection describes when it is necessary to estimate likely future plume extents. Appendix C provides detailed guidance on the application of a specific statistical test to determine whether plumes are expanding or contracting.

¹³ Diffusion and dispersion may also contribute to movement of chemicals in groundwater, though typically to a lesser extent than advection.

2.3.5.1 When is a Likely Future Extents Estimation Necessary in Groundwater?

Likely future extents estimation is generally necessary in groundwater *unless*:

- There is no plume and a future plume is unlikely (this may be true for insoluble chemicals, or for chemicals that leaching tests have shown to be tightly bound to soil)
- The plume has already reached a terminal receptor (when data shows that the plume has already reached a stream, pond, high capacity well, or other destination that is a terminal receptor, IDEM may agree that the extents of the plume are unlikely to expand significantly over time)
- The plume consists entirely of petroleum constituents and is of a certain age [IDEM recognizes that petroleum plumes rarely extend more than 750 feet (Newell and Connor, 1998; Rice et al., 1995), are often much smaller, and usually stabilize within five years of the initial release (Rice et al., 1995)]
- Other lines of evidence show that likely future plume extents delineation is not necessary.
Common lines of evidence that may be relevant for this purpose include:
 - Plumes shown to be shrinking, usually via statistical tests, modelling, the presence of non-regulated degradation products, or other means
 - Plumes with low leading-edge concentrations relative to unconditional remediation objectives
 - Plumes with concentration gradients that decline rapidly with distance, coupled with sufficient distance to the source facility boundary or boundary of an area subject to exposure controls
 - Plumes with low release-related chemical flux

See Section 2.3.5.3 for additional discussion of lines of evidence relevant to likely future extents.

A likely future extents delineation is usually not appropriate when:

- The nature and present extents of release-related chemicals is still under investigation
- Active remediation is occurring, as active remediation alters plume dynamics. A project-specific equilibration period should separate active remediation from plume behavior evaluation.
- The groundwater remediation objective is an unconditional closure
- The groundwater remediation objective is closure via a background or an unrelated source demonstration
- A preferential pathway¹⁴ controls groundwater flow within the affected area
- Other lines of evidence demonstrate that the evaluation is unnecessary

2.3.5.2 Monitoring Well Locations for Likely Future Extents

Accurate representation of future plume behavior in groundwater requires thoughtfully located monitoring wells. The locations most useful to show representative concentrations of the plume over time include the source area, within the known area of release-related chemical migration, and in the direction of groundwater or chemical travel outside the area that exceeds the unconditional remediation objective. Additionally, well locations and results within the plume need to be spatially correlated to explain internal plume dynamics.

Generally, when there is more than one aquifer at a location, the aquifers should be considered separately when calculating representative concentrations and estimating future extents. When there are multiple chemicals in groundwater with concentrations that are not proportional, this recommended approach could result in different samples (e.g., sampling depths) being used to characterize the representative concentrations for a given plume.

¹⁴ See IDEM (2021b) for more on this topic.

The data needed to create an acceptable likely future extents estimate is not typically available during the early phases of characterization. Each release needs to have a robust groundwater conceptual site model that clearly characterizes the nature and extents of the plume(s) before consideration of likely future extents. ITRC (2016) may be useful for estimating the likely future extents of larger or complex plumes.

2.3.5.3 Lines of Evidence Potentially Relevant to Likely Future Extents

Plume behavior is how release-related chemical concentrations change spatially, over time, and interact with potential receptors. Plume behavior evaluation uses applicable lines of evidence to understand the likely future extents of release-related chemicals in groundwater. This in turn allows evaluation of potential exposure scenarios. If plume behavior is not predictable enough to enable a reasonable estimate of future extents, it may be necessary to undertake a groundwater monitoring program of sufficient length to add confidence to the understanding of plume behavior.

Analysis of plume behavior relies on specific knowledge of local conditions. While meaningful statistical tests (see, for example, Appendix C) require substantial monitoring timeframes and consistent monitoring periods to acquire sufficient data, in some situations, concentration trends may be qualitatively discernible in shorter timeframes and/or with irregular time series data. Sometimes, data may show that chemical concentrations in individual wells fluctuate unpredictably, but the overall plume footprint remains unchanged over time. IDEM will evaluate such interpretations on their merits.

Every likely future extents evaluation should begin with qualitative review of geologic, hydrologic, and release-related chemical characteristics. Likely future extents evaluations should also consider other relevant lines of evidence. This section describes several lines of evidence that may be useful in understanding plume behavior. Each line of evidence offers insight into the behavior of the plume, though some are more compelling than others. While no single line of evidence is enough to understand the overall behavior of a plume, agreement among multiple lines of evidence provides greater confidence when predicting plume behavior. It is not necessary to develop any individual line of evidence discussed in this section – only those needed to provide adequate confidence in the understanding of plume behavior. Other lines of evidence may be submitted, and IDEM will evaluate them on a project-specific basis.

Age of the Release. This line of evidence applies directly only to petroleum chemicals. Given the well documented behavior of petroleum releases, the age of the release is an appropriate indicator of the plume lifecycle. Regardless of the size of the release or subsurface conditions, the extent of most petroleum related releases will stabilize within approximately five years (Rice et al., 1995). Given this relationship, IDEM will have greater confidence in the behavior of petroleum plumes that have documented historic release dates. Conversely, the behavior of recent petroleum releases merits less confidence. The approximate age of a cVOC release could be applied in a qualitative assessment of steady-state plume behavior (i.e., the plume is no longer expanding). However, because most cVOCs can naturally degrade to more toxic and more mobile chemicals, any disruption of the subsurface equilibrium eliminates the cVOC plume age as a line of evidence consideration.

Commingled Plumes. Plumes sometimes commingle with other plumes originating from the same or adjacent facilities. In these instances, it can be difficult to differentiate the behavior of one plume from the other. Thus, commingling of plumes reduces confidence in plume behavior. While the presence of commingled plumes does not preclude a thorough understanding of plume behavior, it does require additional information to obtain a greater degree of confidence in the plume behavior.

Groundwater Time of Travel (Exposure Control Area). This line of evidence estimates the time it will take for groundwater to travel from the furthest extent of concentrations exceeding unconditional remediation objectives to the edge of an exposure control area. This line of evidence provides

perspective on the size of the plume relative to an exposure control area. Sometimes, an exposure control area will coincide with the property boundary. In other cases, environmental restrictive covenants or environmental restrictive ordinances may extend an exposure control area beyond the property boundary. Groundwater chemistry and chemical interactions with matrix materials complicate estimation of migration rates and may require location-specific data. IDEM will not consider time of travel estimates as representative if they are contradicted by the known plume extents.

Groundwater Time of Travel (Nearest Receptor). This line of evidence estimates the time it will take for groundwater to travel from the leading edge of the plume where concentrations of release-related chemicals exceed unconditional remediation objectives to the nearest receptor. This line of evidence provides perspective on the size of the plume relative to the location of receptors. IDEM will not consider time of travel estimates as representative if they are contradicted by the known plume extents. Exercise due diligence in identifying any receptors with a high probability of human exposure. Give special consideration to municipal well fields, wellhead protection areas, public reservoirs, rivers, or other potential receptors near plumes. IDEM recommends contacting public water utilities or other significant local water users to determine if there are any planned changes in well locations, pumping rates, or other activities that could influence groundwater elevation or flow direction.

Hydraulic Conductivity. Hydraulic conductivity affects the ability of chemicals to migrate within the subsurface. Hydraulic conductivity estimates must be location-specific, documented, reproducible, and representative of conditions at a scale relevant to chemical transport. Given the potential for greater mobility, high hydraulic conductivities require more robust demonstrations of plume behavior.

Maximum Concentration. The maximum groundwater chemical concentration is an appropriate measure of the relative magnitude of the problem and the confidence level needed to assess plume behavior. Groundwater plumes with maximum concentrations near unconditional remediation objectives require less confidence in plume behavior, while higher concentrations require more confidence.

Persistence. Chemical persistence determines the relative timeframe over which confidence in the plume behavior is needed. Highly persistent chemicals require a greater degree of confidence in plume behavior, while short-lived chemicals require less. Groundwater plumes resulting from petroleum-related releases have been extensively documented and shown to generally migrate and degrade within reasonably predictable parameters. For instance, data indicates that 95% of benzene, toluene, ethylbenzene, and xylene (BTEX) groundwater plumes will terminate within 750 feet of their origin, regardless of the physical properties of the subsurface or the nature of the release (Newell and Connor, 1998; Rice et al., 1995). Conversely, groundwater plumes of chlorinated solvents and other persistent chemicals can extend for long distances – sometimes more than a mile.

Plume Length. A significant body of research shows that regardless of the size of a petroleum release or hydrogeological conditions, benzene will stabilize to 10 parts per billion (ppb) within 750 feet of the release point (Newell and Connor, 1998). Evaluating the length of a plume of benzene against the statistical distribution of benzene plume lengths provides a reasonable indication of the plume's behavior. Longer plume lengths provide greater confidence that the petroleum related plume is nearing its maximum extent, while short plume lengths warrant additional information on the plume behavior. This line of evidence applies only to petroleum chemicals; it does not apply to petroleum additives or special blends (e.g., E85 or methyl *tert*-butyl ether).

Presence of Non-Aqueous Phase Liquid (NAPL). NAPL may be an ongoing source for dissolved plumes and create new source areas. While the presence of NAPL does not preclude understanding the behavior of a plume, it does complicate that understanding. In such cases, additional lines of evidence may bolster IDEM's confidence in the understanding of plume behavior. IDEM will consider dense non-aqueous phase liquid (DNAPL) likely if groundwater concentrations of DNAPL-forming chemicals exceed

ten percent of their solubility, and a potential concern if groundwater concentrations exceed one percent of their solubility (Kueper and Davies, 2009). For light non-aqueous phase liquid (LNAPL), IDEM will not generally request sampling of groundwater in wells where LNAPL thickness exceeds 0.1 foot, although additional investigation may be necessary to determine whether the LNAPL is potentially mobile. If LNAPL thickness is less than 0.1 foot, IDEM may request sampling of groundwater beneath the LNAPL to determine whether the LNAPL may be acting as a significant source of release-related chemicals in that groundwater.

Presence of an Ongoing Source. An ongoing source can prolong the monitoring duration necessary to evaluate plume behavior.

Solubility. Chemical solubility directly relates to mobility, which affects the level of confidence needed in plume behavior. Greater solubility implies a greater need for confidence in plume behavior. IDEM may also consider effective solubilities. See U.S. EPA's [Effective Solubility Calculator](#) for more information on evaluating effective solubilities.

Toxicity. Toxicity is important when evaluating the threat that release-related chemicals pose to a receptor. Highly toxic chemicals require more confidence in plume behavior than do less toxic chemicals. For plume evaluation purposes, IDEM usually gives primary importance to human health effects when considering toxicity.

Variation in Groundwater Elevation. High variability in depth to groundwater reduces confidence in understanding plume behavior. Significant chemical mass can often remobilize when groundwater elevations undergo large fluctuations, which introduces uncertainty in understanding plume behavior. This line of evidence applies only to unconfined aquifers and should be evaluated in the area of the highest dissolved chemical concentrations.

Variation in Groundwater Flow Direction. Groundwater flow is usually the primary driver of plume migration, so understanding groundwater flow direction is fundamental to evaluating plume behavior. A consistent groundwater flow direction lends confidence to the understanding of plume behavior, while highly variable or erratic groundwater flow direction yields less confidence. Highly variable groundwater flow also makes it difficult to determine proper locations for monitoring wells that consistently represent plume conditions. Evaluate this line of evidence based on changes in the calculated groundwater flow direction measured using a minimum of three representative monitoring wells determined to be appropriate by the facility representative and IDEM. While this approach cannot capture all the complexities of groundwater flow, it does provide a consistent measurement.

2.3.6 Present Extents: Vapor

Volatile chemicals may move through permeable soil, fractures in bedrock or clay tills, anthropogenic subsurface structures such as utility lines, sumps, foundations cracks, volatilize directly from groundwater in contact with structures, or any combination of these pathways, often in unexpected directions. If those vapors enter structures at unacceptable concentrations, adverse health effects may result. For this reason, it is necessary to consider the extents of volatile chemicals in the subsurface, including the vadose zone and open conduits like sewers.

2.3.6.1 When is Soil Gas Screening Necessary?

Most release-related vapor intrusion exposures arise from two classes of volatile chemicals –chlorinated volatile organic chemicals (cVOCs) and, to a lesser extent, petroleum-related chemicals. Because the characteristics of chemicals in these classes differ somewhat from each other, criteria that trigger a vapor intrusion evaluation also differ between them. IDEM may require investigation of vapor intrusion potential arising from chemicals in other classes where lines of evidence suggest that is necessary to evaluate potential exposure.

IDEM does not anticipate routinely requiring soil gas delineation at petroleum releases. Instead, IDEM recommends using criteria listed in Table 2-C (Section 2.3.6.5) to decide whether petroleum vapor intrusion investigation is necessary at existing structures, or for potential structures. For cVOCs, soil gas screening should occur at facilities that use, store, dispense, or dispose of cVOCs, or did so historically, and at any facility where sampling data shows or has shown the presence of cVOCs.

2.3.6.2 Soil Gas Screening

Soil gas screening should consider vapors arising from all sources, keeping in mind that different sources may need to be investigated separately. If vapor source locations are known, collect three soil gas samples as close to those sources as possible. For example, when evaluating chemicals in groundwater as a potential vapor source, collect soil gas samples near the groundwater table, starting close to the highest groundwater concentrations (if known and present). When placing samples, keep in mind that vapor does not always migrate in the same direction as groundwater. If the source is unknown, collect three soil gas samples from depths and areas most likely to have exceedances. Examples include locations under buildings, around drains, near machine pits and dry-cleaning machines, in disposal areas, or in fill areas that preferentially accumulate release-related chemicals. Extra caution is warranted when collecting soil gas samples near the soil surface, as ambient air may break through the soil column.

As noted by U.S. EPA (2015), vapor migration in the vadose zone can be impeded by several factors, including soil moisture, low-permeability (generally fine-grained¹⁵) soil and biodegradation. Because of this some circumstances will reduce IDEM's confidence in the representativeness of soil gas screening samples. Examples of circumstances that may warrant postponement of soil gas screening, additional numbers of soil gas screening samples, or additional rounds of soil gas screening include:

- Where soil gas screening occurs during or immediately after a significant precipitation event, defined for this purpose as a total of one inch or more of precipitation over a 72-hour period
- Where volatile chemicals are dissolved in a saturated water-bearing unit under confined conditions, where the confining layer is not laterally extensive (In such cases, vapor may only be evident in the vadose zone in areas where the confining layer has pinched out or otherwise becomes discontinuous, perhaps at a considerable distance from the source facility.)

It is always possible that other circumstances may render soil gas screening results insufficient to rule out additional investigation. Professional judgment will be necessary when considering this possibility.

2.3.6.3 Deciding When Soil Gas Delineation is Necessary

A vapor extents investigation should follow any exceedance of an IDEM published soil gas level. In some cases (see Section 2.3.6.5), the results may indicate that it is also necessary to evaluate vapor intrusion potential at one or more structures.

¹⁵ Where fine-grained soil is classified as clay, silty clay, silty clay loam, or silt consistent with the U.S. Soil Conservation Service classification system.

2.3.6.4 Delineating Present Soil Gas Extents

The same general principles that apply to delineation of present extents in groundwater mostly apply to soil gas delineation, except that the latter occurs only in the vadose zone. Delineation typically begins at or near the vapor source(s) and proceeds laterally until soil gas concentrations no longer exceed levels that would prompt a vapor remedy, an investigation of vapor intrusion potential in nearby structures, or future evaluation of vapor intrusion at subsequently constructed structures. Professional judgment may also suggest that delineation should start at nearby receptors and proceed from there.

Base the number, location, and depth of soil gas samples on the CSM, including known or likely source areas, distance (vertical and horizontal) between the potential vapor source and any receptors, preferential pathways, such as karst and fill areas, and location-specific lithologic and hydrogeologic information. When collecting soil gas samples near a structure, place sample locations as close as possible to the building footprint, as concentrations in samples collected from outside a building footprint are often less than those found in samples collected within the footprint.

2.3.6.5 Prompts for Vapor Intrusion Investigation

Chlorinated Volatile Chemicals

Structures within 100 horizontal feet of an IDEM published residential soil gas level exceedance should undergo a standard vapor intrusion investigation. If the structure is subject to a residential use restriction, then exceedance of an IDEM published commercial soil gas level should prompt a standard vapor intrusion investigation.

Petroleum-related Volatile Chemicals

Vapor intrusion by benzene and other petroleum-related chemicals occurs most often when groundwater containing release-related chemicals is inside a building (e.g., in the well of a sump pump) or in contact with a building foundation, or NAPL is located near a building foundation. Benzene, the petroleum-related chemical that most often drives risk resulting from petroleum vapor intrusion, readily degrades in unsaturated, oxygenated soil (U.S. EPA, 2012). Soil in Indiana is generally sufficiently aerated if it is unsaturated.

IDEM will not initially require soil gas sampling for petroleum releases but will evaluate vapor potential based on the scenarios listed in Table 2-C, below. Evaluation of vapor intrusion may be appropriate at structures on:

- Properties near operating/formerly operating gasoline stations
- Properties near operating/formerly operating petroleum bulk storage facilities
- Properties that used, stored, dispensed, or disposed of petroleum products

High benzene concentrations in ambient air at operating gasoline stations can confound indoor air sampling results in vapor intrusion studies. If impacts are from facility operations (current or historic fuel station operations), IDEM will not typically request vapor intrusion evaluations of structures at operating facilities. If impacts at a petroleum facility are from a release at a different petroleum facility, a vapor investigation of the subsurface may be warranted for future use considerations but again, due to confounding issues with ambient air concentrations, IDEM will not typically request a standard VI investigation. SGe sampling may be used to rule out vapor intrusion and future vapor investigations at active fuel stations under appropriate circumstances as long as preferential pathways aren't facilitating vapor intrusion.

Table 2-C: Prompts for a Petroleum Vapor Intrusion Investigation

Indicator	Vapor Investigation Recommended if:
NAPL	Building has less than 15 feet of vertical or horizontal separation from NAPL
Groundwater	Building has less than six feet of vertical or horizontal separation from groundwater with dissolved benzene above 50 ug/L
Soil	Building has less than six feet of vertical or horizontal separation from soil containing volatile petroleum chemicals
Odors	Building occupants near the petroleum source area complain of chemical odors

Section 3.4.7 provides guidance on deciding whether vapor intrusion investigation results should prompt a remedy.

2.3.6.6 When is Conduit Vapor Screening Necessary?

IDEM will request conduit vapor screening for cVOCs if groundwater containing release-related chemicals potentially intersects the conduit or cVOCs may have been dumped or disposed of down facility drains. Conduit samples may also be necessary if paired sampling yields ambiguous results and no clear indoor air source can be determined. IDEM will request initial evaluation of conduits for petroleum vapor if groundwater containing NAPL or benzene of 500 ug/L or greater is being or has the potential to be released into conduits.

2.3.6.7 Conduit Vapor Screening

Collect conduit vapor samples at the maintenance opening closest to the infiltration or release point and at one maintenance opening upgradient and two maintenance openings downgradient of that location. An evaluation of the conduit's structural condition may be needed, especially if release-related chemicals have the potential to enter the conduit. This evaluation may include a camera inspection of subsurface drains, a visual inspection of drains or open piping within structures and documentation from the entity that maintains the conduit regarding any major changes or upgrades to the conduit.

IDEM understands that commingled vapor sources may exist in these conduits. However, if the facility contributed release-related chemicals, either through a release resulting in infiltration to the conduit or through direct discharge, then it must address the impact even though it may not be the sole contributor. If the facility can demonstrate that it is not contributing to the release-related chemicals or that different and distinct chemicals exist in addition to its contribution, IDEM will pursue other sources.

2.3.6.8 Deciding When Conduit Vapor Delineation is Necessary

If conduit screening results exceed IDEM's published levels, conduit delineation should continue until IDEM's published levels are no longer exceeded. If conduit screening results do not exceed IDEM's published levels, quarterly sampling (for a year) should continue for chlorinated chemicals, unless lines of evidence demonstrate otherwise. For petroleum chemicals, a second confirmatory conduit vapor sampling event should occur during a subsequent quarter.

2.3.6.9 Delineating Conduit Vapor

Use IDEM's conduit vapor published levels to delineate the extents of release-related chemicals within a conduit. IDEM's conduit vapor published levels currently apply an attenuation factor to the respective

IDEM indoor air published level for a chemical. Attenuation factors may change, pending new developments in vapor intrusion research. If so, updates will be provided and explained in an IDEM technical guidance document and reflected in IDEM's subsequent published levels tables. Development of project-specific conduit attenuation factors is acceptable if it can be shown, under worst-case building conditions, that VI will not occur now or in the future.

2.3.6.10 Prompts for Vapor Intrusion Investigations Based on Conduit Vapor Sample Results

If conduit vapor concentrations in the main conduit exceed IDEM's conduit vapor published levels, IDEM is likely to request vapor intrusion investigations in nearby structures. IDEM staff are available for consultation during work plan development.

If building owners will not allow access, collection of vapor samples from laterals extending from the utility main to the building may be used, though additional sampling precautions will likely be necessary. If the lateral has a cleanout, consider plugging it to obtain a more representative sample, as cleanouts are likely not vapor tight. Research has shown that vapor concentrations in laterals leading from the main conduit can fluctuate greatly (McHugh and Beckley, 2018), so multiple lateral sampling events may be necessary to rule out the lateral as a source of vapor intrusion.

If conduit vapors cause indoor air to exceed IDEM's published indoor air levels, a remedy for the affected structure(s) is likely necessary. If conduit vapor concentrations are high enough, a remedy to protect against potential future exposures may be necessary, even if indoor air concentrations do not currently exceed IDEM's published indoor air levels. Consult Section 3.4.7 for guidance on remedy necessity determinations.

2.3.7 Likely Future Extents: Vapor

Because both vapors and their sources can move through the subsurface, vapor extents can change over time. New receptors may also arise, as when a new home is built. When either of these things happens, vapors may affect receptors that were not previously affected or present. For this reason, it is necessary to consider the likely future extents of subsurface vapor, both in soil gas and in preferential pathways.

2.3.7.1 When is a Likely Future Extents Estimation Necessary in Subsurface Vapor?

Consider the following when estimating likely future extents of subsurface vapor:

- Is the source of the subsurface vapor expanding (e.g., when a release-related chemical plume in groundwater is acting as a vapor source and is expanding) and unlikely to have reached its maximum extent?
- Is there a continuing release to a preferential pathway or subsurface conduit?
- Is there capped or covered soil that, if uncapped, could leach volatile chemicals to groundwater and create or expand a plume of release-related volatile chemicals in groundwater, thereby potentially increasing the extent of vapors in the subsurface?

If the answer to any of these questions above is yes, it will be necessary to estimate the likely future extents of vapors. If the vapor source is expanding, it may be appropriate to consider the placement of "sentinel" soil gas probes. A sentinel soil gas probe is a permanent soil gas sampling point located between the current lateral extent of the release-related chemicals in soil gas and a potential vapor receptor. Its purpose is to warn of a soil gas plume that is expanding in the direction of potential receptors.

2.3.7.2 Estimating Likely Future Extents in Subsurface Vapor

When a release-related chemical plume in groundwater is acting as a source of subsurface vapor, the future extents of subsurface vapor are likely to be influenced by the future extent of those chemicals in groundwater. In some cases, it may be necessary to iteratively sample subsurface vapors as they move laterally from an expanding source until the likely future extent of those vapors is understood.

Properties with residual release-related chemicals in soil and/or groundwater may pose a threat of vapor exposure if buildings are constructed in the future. The potential for future exposure can be assessed through methods such as SGe sampling or groundwater sampling. When suitably constructed, documented, and validated using data that fully characterizes the potential subsurface vapor sources and associated conditions in the vadose zone, mathematical models can provide an acceptable line of evidence supporting risk management decisions pertaining to vapor intrusion.

2.3.8 Extents in Other Media

Sometimes releases extend into media other than soil, groundwater, or vapor. In the absence of compelling lines of evidence showing that it is not necessary to do so, IDEM will require delineation efforts to follow releases wherever they go, regardless of medium.

2.3.8.1 Extents in Fill

In the context of this document, fill is material used to modify land topography. Fill comprised of waste deposited onto the land as a means of disposal may be subject to solid or hazardous waste regulations and will require a project-specific approach that is beyond the scope of this guidance.

Fill areas can complicate CSM development. Fill alters local hydrogeologic conditions and may contain chemicals in common with those from a release. Sometimes it is difficult to distinguish fill from waste fill that is subject to regulation. These challenges make it especially important to have a clear understanding of sampling objectives when sampling fill or in fill areas. Sometimes the objective may be to characterize a release in a fill area. In other cases, the objective may be to characterize the fill itself as a potential source.

With sufficient knowledge of the fill material(s) and their location(s), standard or slightly modified standard methods for sampling surface or subsurface soil may be suitable for collecting fill samples. However, it may be difficult to collect a representative sample of fill material, especially if the material is too heterogeneous, or there is little or no information on the source of the material. U.S. EPA (2019d) contains guidance on developing a sampling plan for fill material. In some cases, adequate characterization of fill material may cost more than removing it.

2.3.8.2 Extents in Sediment

Extents determinations in aquatic sediment typically employ different sampling equipment and techniques than those used in extents determinations in soil. Delineation criteria may also differ, as ecological criteria (e.g., U.S. EPA, 2018) often apply and may result in lower remediation objectives than those that apply to human health risk assessment. Burton (1998), ITRC (2011), and U.S. EPA (2001, 2020b) contain technical guidance on sediment sampling.

2.3.8.3 Extents in Surface Water

[327 IAC 2-11-5\(3\)](#) states that “for waters of the state¹⁶, surface water quality standards¹⁷ shall be met in the surface water at the groundwater – surface water interface.” Pore water samples are technically most appropriate for this purpose. Note that mixing zones, while applicable to some National Pollution Discharge Elimination System (NPDES) permits, do not apply to unpermitted releases to waters of the state.

2.3.9 How IDEM Will Evaluate Extents Determinations

In most cases, IDEM will require the following to evaluate extents determinations:

- An overview map showing all relevant features including, but not necessarily limited to, property lines, facility property use, surrounding property use, and subsurface utilities
- Source facility, source point(s), and source area(s) identified, as relevant and known
- Observed concentrations for all affected media, legibly tabulated and supported by laboratory and field sheets
- Map(s) illustrating the extents relative to unconditional remediation objectives in all directions for all affected media, including applicable cross sections, supported by legible tabulated results, laboratory, and field sheets
- Adequate documentation for unrelated sources, if relevant, including release-related chemical concentration gradient data, location and operational history of any unrelated source(s), groundwater flow direction, time-series groundwater data, and other relevant project-specific documentation as available

Every release is different, and the number, location, and quality of sample points will vary based on the chemicals released, local geology, and the location and nature of potential receptors.

¹⁶ [IC 13-11-2-265](#) defines waters of the state.

¹⁷ [327 IAC 2-1-6](#)

3. Risk Evaluation

For purposes of this document, risk evaluation is the process of determining whether a release warrants a remedy. Risk evaluation is necessary to fulfill statutory obligations under [IC 13-25-5-8.5\(c\)](#) to protect human health and the environment. Every release that requires characterization also requires some level of risk evaluation.

Risk evaluation complexity varies. The risk evaluation process may be fairly simple, involving a few numerical comparisons, or it may include complex tasks like statistical evaluation of large sample data sets, target cancer risk adjustments, development of site-specific remediation objectives, or evaluating the relevance and sufficiency of different lines of evidence in a remedy decision.

Section 3 describes four broadly defined tasks that comprise a risk evaluation:

- Task Four: Specify decision units and their likely uses (Section 3.1)
- Task Five: Determine representative concentrations (Section 3.2)
- Task Six: Specify remediation objectives (Section 3.3)
- Task Seven: Determine whether a remedy is necessary (Section 3.4)

There is some flexibility with respect to the task order. For example, a responsible party that decides to specify remediation objectives allowing unlimited use of a property might do so at the onset of a project, well before performing any risk evaluation tasks. Projects should proceed in a reasonably systematic way that makes sense given the circumstances of the release, and at a pace that results in timely implementation of remedies that address any unacceptable risks arising from the release. Note, however, that per [IC 13-25-5-8.5\(c\)\(1\)](#), a *complete* evaluation of risk relies on and requires adequate characterization of the nature and extent of release-related chemicals.

Each task subsection includes the statutory basis of IDEM's authority to require the task and related information, as well as the corresponding scientific reasons why the task is necessary. The task subsections also describe one or more ways to perform the tasks. *IDEM recognizes that alternative approaches to performing these tasks may exist, and that those alternatives may be acceptable or preferable for any number of reasons.* IDEM will evaluate alternative approaches on their merits.

It is sometimes immediately apparent that a release poses an unacceptable risk, and that it is necessary to implement a remedy as soon as possible. In other cases, responsible parties may opt to implement an interim remedy (e.g., removal or treatment of known source material) before completing characterization, provided the interim remedy does not create an unacceptable risk. In many instances, implementation of an interim remedy may significantly reduce overall remedy cost and timeframes. Section 4 includes discussion of interim remedies and other remedy options.

3.1 Task Four: Specify Decision Unit(s) and Their Use(s)

The remedy decision process described in [IC 13-25-5-8.5\(b\)\(2\)](#) requires a comparison of levels of hazardous substances or petroleum (what this guidance refers to as **representative concentrations**, Section 3.2) against remediation objectives. For purposes of this guidance, IDEM refers to the places where such comparisons and decisions occur as **decision units**.

3.1.1 Basis for Requirement

Responsible parties must specify decision units so that IDEM knows *where* comparisons of representative concentrations and remediation objectives are occurring, and so that IDEM can ensure that all places within the present and likely future extents of releases are evaluated to determine whether a remedy is necessary. Defining current and likely future use of decision units is necessary when selecting remediation objectives that are adequately protective for those uses under [IC 13-25-5-8.5\(b\)\(2\)\(A\)](#). Unless decision units are specified, it is not possible to know whether they meet the requirements for characterization described in Section 2, or whether a remedy is necessary under [IC 13-25-5-8.5\(c\)](#).

3.1.2 Specifying Decision Units

Every risk evaluation will involve at least one decision unit, and every location within the present and likely future extents of release-related chemicals must be in at least one decision unit. Some releases may lie entirely within a single decision unit. Other releases may require multiple decision units. Decision units can be specified for areas, volumes, or relatively compact places such as a drinking water tap. A decision unit might be soil in a residential yard, groundwater beneath a property, the air inside an occupied structure, or any other place within the present or likely future extents of a release. They can be places where exposure is currently occurring, or places where exposure might occur in the future.

Decision unit boundaries typically coincide with one or more of the following:

Physical boundaries

This is especially important when specifying decision units for evaluation of indoor air. Individual houses would typically each be a separate decision unit for purposes of vapor remedy decisions. Strip malls and apartment complexes are examples of subdivided structures where indoor air exposures may differ significantly across different parts of the same structure. Reasons for such differences might include proximity to release-related chemicals, indoor chemical use, differences in building construction, including ventilation systems and other design characteristics, and differences in the way that the structures have aged or been modified.

Different exposures

Exposures may vary for many different reasons. For example, differences in exposed populations, their activities, and their developmental stages mean that soil exposure risk is likely to differ significantly between a children's playground and an office building occupied by adults. For this reason, if a large property or area is divided into many different uses or subject to different types of exposures, each area subject to a different use or exposure should be designated as a separate decision unit. Alternatively, the entire property or area could be assigned to a single decision unit and evaluated assuming exposure to the most sensitive population.¹⁸

¹⁸ Per 328 IAC 1-3-1.3(b)(5), this approach may not be eligible for reimbursement from the Excess Liability Trust Fund.

Different exposure controls

Some locations may have different exposure controls. For example, an adjacent property owner affected by a release may not be amenable to a land use restriction, even if that restriction adequately controls risk. In such cases, a decision unit boundary might coincide with the property boundary.

Data availability

In most cases, IDEM will expect that remedy decisions for a decision unit be supported by representative concentrations based on data *from that decision unit*. For example, it would not ordinarily be appropriate to base an indoor air remedy decision on data from a structure three blocks away. However, there are times when interpolation and extrapolation may be appropriate or even necessary. For example, if the extents of a plume of release-related chemicals in groundwater encompasses many drinking water wells, it may be acceptable to assume that well users in the interior of the plume require a remedy to control exposure to those chemicals, even if some of the wells in the interior of the plume are not sampled. In other cases, appropriate sampling locations may be inaccessible. IDEM will evaluate such situations on their merits.

Decision unit specifications should include:

- Descriptions of decision unit boundaries or locations (areas or volumes), including likely uses
- A list of decision units
- A depiction of decision units on a map

Note that while co-mingled plumes or multiple releases may complicate characterization or responsible party identification, risk evaluation should focus on release-related chemicals in the decision unit, regardless of source. Unacceptable risks must be controlled, even those arising from more than one source. IDEM will require parties associated with co-mingled plumes to prioritize and control unacceptable risks to human health and the environment before litigating financial responsibility related to the multiple releases. Assignment of financial responsibility for controlling risk is a separate question from determining the need for such control.

3.1.3 Decision Unit Use(s)

Risks should be evaluated for both current and reasonably likely future uses of the locations within decision units. IDEM acknowledges that predicting future extents and uses is often difficult, that some degree of uncertainty is inevitable and acceptable, and that it is not reasonable to base future use projections on any conceivably possible use. IDEM will apply available knowledge about the release and its setting when evaluating whether the projected future use is reasonably likely, and whether the proposed remediation objectives are reasonably likely to be protective. Any determination of reasonably likely future use is necessarily a judgment call. However, in the absence of an IDEM-enforceable environmental restrictive covenant that restricts use of a location affected by a release¹⁹, IDEM will typically assume that likely future exposure will include sensitive (e.g., residential) populations. This is because land use changes are common (including, for example, conversion of former industrial facilities to residential use).

A proposed change in use of a decision unit will require IDEM to evaluate additional information to support an evaluation of risk regarding the proposed change in use. The parties involved in any such transaction involving a change of use are responsible for coordinating with each other, collecting, and

¹⁹ Or, in the case of groundwater, an environmental restrictive ordinance (Appendix F) may also be applicable.

evaluating the additional information, and presenting it to IDEM. Examples of appropriate questions to ask in such circumstances include (but are not limited to):

- Will existing buildings be demolished or renovated?
- If an existing building will be renovated, is it possible to determine in advance whether any proposed remedies are likely to be effective, or must that determination wait until the renovations are complete?
- Will building spaces (e.g., a basement) be used for storage, or to house sensitive populations?
- Will the grounds be used as a playground, or for gardening, or as public outdoor space?

These unknowns may have to be resolved by managing the exposure risk and restricting use of the decision unit until a transaction is complete and the person who intends to change the use of that decision unit collects the additional information and presents adequate evidence to IDEM regarding exposure risk before modifying the existing use restrictions. All parties must work together and coordinate plans to address both development and environmental concerns so that the goals of both can be effectively and expediently addressed.

3.1.4 How IDEM Will Evaluate Decision Unit and Future Use Specifications

IDEM will use the following criteria to evaluate the specification of decision units and their current and likely future uses:

- Is every location within the present and reasonably likely future extents of release-related chemicals within at least one decision unit?
- Are decision units depicted on a map or figure, and listed?
- Is the present and reasonably likely future use of each decision unit specified?
- Where environmental restrictive covenants or environmental restrictive ordinances are either in place or planned for specific decision units, is that information included in the listing or description of those decision units?
- If an environmental restrictive covenant or environmental restrictive ordinance is not already in place, is it anticipated, and what steps have been taken and are planned to obtain institutional controls on each decision unit?
- Are the decision unit boundaries reasonable, given physical barriers, likely exposures, likely or proposed exposure controls, and data availability?

3.2 Task Five: Determine Representative Concentration(s)

A **representative concentration** is an estimate of the concentration of a release-related chemical in a particular medium within a decision unit. Sampling errors, laboratory errors, and the typically heterogeneous nature of release-related chemical distribution in environmental media all contribute to uncertainty when determining representative concentrations. For these reasons, IDEM has determined that conservative approaches are appropriate when determining representative concentrations.

Sometimes it is necessary to resample an area and derive new representative concentrations. For example, resampling is necessary if a responsible party wishes to demonstrate that removal, natural processes, or treatment activities have reduced concentrations of release-related chemicals. As in all phases of environmental projects, obtaining meaningful data requires that data collection activities be consistent with achievement of appropriate DQOs. See Section 2.2 for guidance on DQOs.

3.2.1 Basis for Requirement

Representative concentrations are required to perform either the comparison described in [IC 13-25-5-8.5\(c\)\(2\)](#), or as part of a formal risk assessment consistent with [IC 13-25-5-8.5\(b\)\(2\)](#).

Absent controls that eliminate exposure, there is a direct relationship between the concentrations of released chemicals in a decision unit and the dose received by persons or organisms in that decision unit. Dose received is in turn related to the probability or intensity of adverse health effects, if any. For this reason, knowledge of the concentrations of release-related chemicals in media within decision units is a critical component of the risk evaluation process.

3.2.2 Determining Representative Concentrations

Sampling and analysis of environmental media are typically used to determine concentrations of release-related chemicals in those media²⁰. Acceptable approaches may differ significantly across media or by chemical. The remainder of Section 3.2 describes some methods that IDEM considers acceptable for determining representative concentrations. It is not a comprehensive treatment, and *IDEM recognizes that other approaches may be acceptable or even preferable, depending on project-specific circumstances*. IDEM will evaluate representative concentration determinations on their merits.

3.2.2.1 Determining Representative Concentrations in Soil

There are several possible approaches to deriving representative concentrations for release-related chemicals in soil. Preferred approaches will likely vary with present and reasonably likely future land use, likelihood of excavation, and the physical characteristics of the chemicals under investigation. Knowing where to collect samples based on likely exposure is important when determining representative concentrations in soil.

For example, the greatest risk from recreational exposure at a city park is often from routine exposure to release-related chemicals in the top few centimeters of soil. Gardening or landscaping activities may result in soil exposure risk from release-related chemicals in soil to a depth of two feet or more. Deeper soil, once excavated and left on the surface, may pose a future exposure risk. Similarly, where excavation or utility work is reasonably likely to expose workers to soil below the ground surface, the chemicals in that soil warrant evaluation for exposure risk. The most relevant samples for evaluating risk are those from locations and depths where exposure is most likely to occur, now and/or in the future.

²⁰ Modeling (when predicting future concentrations), interpolation (for decision units inside plumes), and extrapolation (decision units outside plumes) may be preferable or necessary in some circumstances.

The distribution of release-related chemicals is important when evaluating potential soil exposure risk. For example, an isolated “hot spot” of release-related chemicals in subsurface soil is less likely to be excavated and become surface soil than is a larger area of subsurface soil that also contains release-related chemicals. Vertical distribution is also important. Shallower soil is more likely to be excavated than deeper soil. IDEM considers it generally unlikely that soil deeper than 15 feet below ground surface will be brought to the surface in the future, and in *most* cases, it is not necessary to evaluate soil deeper than 15 feet for exposure risk. However, if there is reason to believe that excavation work will occur at depths greater than 15 feet below ground surface and release-related chemicals are reasonably likely to extend more than 15 feet below the ground surface, then soil deeper than 15 feet below the ground surface should be sampled and evaluated for risks associated with those chemicals. Data on the concentrations of release-related chemicals under physical barriers is necessary to determine whether the barrier needs to remain in place to control future soil exposure risk.²¹

Treat Each Sample Result as a Representative Concentration

The simplest and most common approach is to treat each observed concentration as a representative concentration. This approach can, and often does, use data already collected during characterization activities, and for that reason may offer significant cost savings. It may also reduce the number of samples necessary outside the area of known impacts, if the source and extents of the release are well understood and there is good reason to believe that there have been no additional releases.²²

Where screening instruments or other indicators of chemical presence are used to preferentially choose sampling locations with the highest indications within a given decision unit, observed concentrations are likely to be on the high end of the concentration distribution for that area. This means that the representative concentrations obtained in this manner are likely to overestimate actual exposures, and that those representative concentrations are likely to be conservative, sometimes very much so.

When compositing, analyze an aliquot of the composite and treat the result as a representative concentration of the area covered by the individual sample locations that comprise the composite. Compositing may be advantageous when analytical costs are high and there is no need for information on concentration variability or extreme observations. Compositing is *not* appropriate when the compositing process itself is likely to result in significant attenuation of the chemicals of interest. This is a particular concern for volatile chemicals.

Calculate an Upper Confidence Limit of the Mean (UCL) and use it as a Representative Concentration

This is a good approach when evaluating risk over an entire decision unit without giving undue weight to the highest observed concentrations. It is appropriate for randomly or systematically placed sample arrays, and occasionally for judgmentally placed sample arrays that sufficiently cover a decision unit. Random sampling involves placing sampling locations on a defined grid using a random number generator, so that each location in a decision unit has an equal chance of being sampled. Systematic sampling uses a random number generator to guide placement of the initial sample, and then arrays additional sample locations across the decision unit at predetermined distance intervals or in a fixed pattern.

Sampling subsurface soil under this approach is a two-step process. First, use a procedure from the preceding paragraph to establish boring locations. Then collect at least one sample from each boring at

²¹ A related purpose for such sampling is to decide whether the barrier should remain in place to prevent or impede leaching of release-related chemicals to groundwater.

²² Note that some IDEM programs may require sampling of all areas covered under a closure document.

the depth(s) with the highest screening instrument response and/or other indicator of the presence of release-related chemicals.

IDEM will not accept systematic or random sample arrays that fail to include sample locations within a reasonably representative selection of areas affected by the release, including areas close to the source. Representative concentrations derived from systematic or random sample arrays that do not include sample results from a representative selection of areas affected by the release ignore important information and are likely to result in inadequate representative concentrations.

For systematically collected samples, the representative concentration is an appropriate UCL, one for each release-related chemical, using results from a sample array that represents the decision unit under evaluation. There are many kinds of UCLs, and the appropriate UCL depends on several factors, particularly the distribution of the data. Further discussion of the mechanics of UCL calculation and selection are beyond the scope of this document. Instead, IDEM recommends using a software application that can perform the necessary calculations and recommend an appropriate UCL. For example, ProUCL is an application suitable for this purpose, and is available for [free download](#) from U.S. EPA. Whatever the approach or software used, IDEM review of UCL calculations will require submission of algorithm inputs and outputs.

Where judgmentally collected soil samples are of sufficient spatial density and distribution to adequately cover the area under evaluation, it may be appropriate to use the data to calculate a UCL for use as a representative concentration. The acceptability of this approach is necessarily a judgment call and will depend on whether the spacing and distribution of sample results provides sufficient confidence that the data adequately represents potential exposure to release-related chemicals across the decision unit.

Calculate an Arithmetic Average and use it as a Representative Concentration

This approach is appropriate for lead. Because the models²³ that U.S. EPA and IDEM use to derive their published levels for lead use central tendency parameters, U.S. EPA (2003, 2007) suggests basing representative concentrations for evaluation of soil exposure risk from lead on the arithmetic mean (unweighted average) of lead samples. For this reason, appropriate lead representative concentrations are arithmetic averages of results from each decision unit. While U.S. EPA guidance (U.S. EPA, 2003b) focuses on residential yards, the arithmetic mean is also appropriate for larger areas, including those used for nonresidential purposes, provided the sample design reasonably represents exposure across those areas. Sample depths should reflect exposures associated with the reasonably likely land use. Section 4.3.2 of U.S. EPA (2003b) discusses appropriate lead sampling depths, and Section 4.2 of the same document provides detailed guidance on appropriate lead sampling design.

Future Concentrations of Release-related Chemicals in Soil

Release-related chemicals in soil are potentially subject to several influences (e.g., volatilization, leaching, microbial degradation, etc.) that may affect their concentrations over time. For example, volatile chemicals are unlikely to persist in the top two centimeters of the soil profile for a significant fraction of the years of exposure assumed when calculating U.S. EPA's published levels for residential soil. Other chemicals are relatively nonvolatile and insoluble and may remain available for soil exposure for centuries or more. Effects on the concentrations of other chemicals are more difficult to predict, and may vary according to many factors (chemical characteristics, including volatility; the soil matrix; environmental conditions, etc.) For this reason, *IDEM will assume, unless presented with sufficient lines of evidence to*

²³ The Integrated Exposure Uptake Biokinetic (IEUBK) Model for residential child exposure and the Adult Lead Methodology (ALM) for commercial and industrial exposures.

the contrary, that release-related chemicals in soil are likely to remain indefinitely at concentrations similar to those observed during the last round of sample collection.

3.2.2.2 Determining Representative Concentrations in Groundwater

IDEM recommends either of two basic approaches, both described below, when determining groundwater representative concentrations. However, IDEM will consider other approaches on their merits. As with soil, it is sometimes necessary to resample groundwater and derive new representative concentrations prior to making or re-evaluating a remedy decision. For example, resampling from adequately installed monitoring wells is appropriate following active remediation of release-related chemicals, or when other forces have attenuated concentrations of those chemicals in groundwater.

Active remediation greatly changes the subsurface system, so a re-equilibration period is necessary before beginning a representative concentration determination. Samples collected during re-equilibration may not be representative of steady-state conditions. A typical re-equilibration period is twelve months, but IDEM will evaluate proposals for shorter or longer periods on their merits. Sampling after active remediation should continue to determine whether release-related chemical concentrations in groundwater rebound. The length of that monitoring period will necessarily depend on project-specific conditions and the adequacy of the CSM. Four quarters is typical (eight when calculating a UCL), with some releases requiring more extended monitoring.

Some releases may affect groundwater in more than one aquifer. Where this is the case, remedy decisions for a decision unit must be based on the worst-case aquifer. Because release-related chemicals dissolved in groundwater can move from unusable water-bearing units into aquifers, remedy decisions for groundwater must consider the possibility of future unacceptable risk to aquifers from such movement.

Treat Each Sample Result as a Representative Concentration

The first highlighted approach defines each groundwater analytical result for each release-related chemical as a representative concentration. This is the simplest and most common approach. It can and often does use data collected during characterization activities. Although the potential number of representative concentrations under this approach can be quite large (as large as the arithmetic product of the number of release-related chemicals, the number of monitoring points, and the number of sampling events) it is common and acceptable to focus on those release-related chemicals most likely to trigger the need for a remedy.

Where groundwater concentrations of release-related chemicals vary significantly (e.g., due to drought, seasonal groundwater elevation changes, irrigation, or other withdrawal, etc.), use the highest observed concentrations within the decision unit as the representative concentration or calculate an appropriate UCL (see below). However, because release-related chemical concentrations in groundwater tend to change over time, it is generally preferable, unless project-specific circumstances suggest otherwise, to base remedy decisions on relatively recent data.

Calculate an Upper Confidence Limit of the Mean (UCL)

This approach calculates an appropriate UCL for each release-related chemical in each monitoring well, and defines those UCLs as representative concentrations. UCL calculation requires at least eight quarters of groundwater data, collected *after* an equilibration period following any active remediation. For wells with many quarters of data, UCLs calculated using only the last eight quarters usually provide a better indicator of current conditions than UCLs calculated using the entire data set.

UCLs based on strongly trending groundwater concentrations may be elevated due to large variation in observed concentrations. Strongly trending concentration data typically indicates either an improving or

worsening situation, and trend analysis will often weigh heavily when making remedy decisions. Appendix C provides additional guidance on those decisions.

There are many kinds of UCLs, and the appropriate UCL depends on several factors, particularly the distribution of the data. Further discussion of the mechanics of UCL calculation and selection are beyond the scope of this document. Instead, IDEM recommends using a software application that can perform the necessary calculations and recommend an appropriate UCL. For example, ProUCL is an application suitable for this purpose, and is available for [free download](#) from U.S. EPA. Whatever the approach or software used, IDEM review of UCL calculations will require submission of algorithm inputs and outputs.

Future Concentrations of Release-related Chemicals in Groundwater

Because groundwater flows, it can sometimes transport release-related chemicals over long distances. For this reason, it is important to consider the likely future extents of release-related chemical concentrations in groundwater that exceed residential remediation objectives, and therefore define areas likely to require a groundwater remedy. Section 2.3.5 provides guidance on estimating likely future extents of release-related chemicals in groundwater. If estimating the likely future extents of release-related chemicals in groundwater is not possible, then other actions may be necessary, such as active remediation of the plume or long-term monitoring.

3.2.2.3 Determining Representative Concentrations in Vapor

One or more of several vapor sampling approaches may be relevant when predicting whether indoor air exposure is likely to occur, and results from those sampling efforts may drive a remedy decision that is independent of current indoor air results. For example, while indoor air concentrations most often drive remedy decisions, crawl space air, subslab vapor, or soil gas results may also indicate significant potential for future vapor intrusion and the need for a remedy, regardless of indoor air results. However, *actual exposure* to vapors arising from releases to the land usually occurs via the air within structures (indoor air). Indoor air samples intended to measure actual exposure should be collected in breathing zones in the most frequently occupied interior area(s) of structures.

An exceedance of an IDEM published level in indoor air does not necessarily mean that the exceedance is the result of vapor intrusion from the subsurface. Indoor sources of release-related chemicals are surprisingly common, and that is the basis of this document's emphasis on paired sampling and, where applicable, surveys of building contents to identify stored or frequently used products that contain the same chemicals as those associated with the release. Batch-certified canisters are generally acceptable, though individually certified canisters may be advisable if false positives are a concern.

Vapor concentrations, particularly in structures, are highly variable, and may exhibit marked changes based on season, time of day, ventilation system operation, or any number of other factors, some of which are poorly understood. For this reason, IDEM recommends a conservative approach to determining vapor representative concentrations. Unless potentially acute exposures are likely and immediate sampling is necessary, or some other compelling reason prevents doing so, indoor air sampling should occur during "worst-case" conditions as defined in Section 2.2.6. Further, the inherent variability of vapor sampling results means that, unless sample results exceed indoor air action levels, IDEM is reluctant to make remedy decisions based on a single round of sampling. A single sample result above or below an IDEM published level usually does not constitute enough evidence to establish or rule out unacceptable vapor risk.

Treat Each Sample Result as a Representative Concentration

This is by far the most common approach. Pooling indoor air data and calculating arithmetic averages from samples collected at multiple sampling locations within a structure during a single monitoring event is not acceptable.

Calculate an Upper Confidence Limit of the Mean (UCL)

IDEM will consider indoor air UCLs calculated using at least eight sample results collected over eight worst-case sampling rounds from the same location within a structure. If planning to develop a UCL, consult with your IDEM project manager to determine if this is appropriate for the building.

Future Concentrations of Release-Related Chemicals in Vapor

Like groundwater, vapors flow, sometimes over long distances. This is particularly true when preferential pathways exist. The nature of the vapor source can also affect the future extents of soil vapors. For example, vapors arising from release-related chemicals in soil underneath a building foundation *may* eventually assume a relatively steady-state distribution. However, the distribution of vapors arising from a migrating chlorinated solvent plume in groundwater may change as that solvent plume flows. If release-related chemicals in groundwater are a source of vapors that result in indoor air risk, then predicting the likely future extents of potential vapor exposure will depend in part on understanding the behavior of the groundwater. If establishing the likely future extents of release-related chemicals in vapor is not possible, then other actions may be necessary, such as active remediation of the vapor source, or long-term monitoring.

3.2.2.4 Determining Representative Concentrations in Other Media

It is occasionally necessary to sample other media affected or potentially affected by a release to the land. Sediment and surface water are probably the most common examples. Representative concentration calculation procedures suitable for soil are, in general, applicable to sediment. For example, it is acceptable to treat each sediment sample result as a representative concentration, to calculate a UCL from a systematic array of sediment sample results, or to calculate an arithmetic average for lead results.

[327 IAC 2-11-5\(3\)](#) states that “for waters of the state²⁴, surface water quality standards shall be met in the surface water at the groundwater – surface water interface.” Pore water samples are technically most appropriate for this purpose. IDEM will evaluate proposals to use UCLs as representative concentrations when those UCLs are calculated based on systematic arrays of pore water samples, but in the vast majority of cases, IDEM expects that each pore water sample result will be treated as a representative concentration. Note that mixing zones, while applicable to some National Pollution Discharge Elimination System (NPDES) permits, do not apply to unpermitted releases to waters of the state.

²⁴ [IC 13-11-2-265](#) defines waters of the state.

3.2.3 How IDEM Will Evaluate Representative Concentration Determinations

IDEM evaluation of the adequacy of representative concentration determinations will include, but may not be limited to, the following factors, where relevant:

General Considerations

- Were representative concentrations determined for each release-related chemical in all affected media in each decision unit?
- Were sample locations and sample density representative for each decision unit?
- Did the sample array include locations in the area(s) where concentrations of release-related chemicals are likely to be highest?
- Does the sample data reflect current conditions?
- Did enough time separate active remediation activities and post-remediation sampling to allow sufficient subsurface re-equilibration?
- Are UCL calculations based on at least eight spatially and/or temporally independent sample results?
- Were copies of software inputs and outputs provided along with UCL results?

Soil

- Were samples collected at depths most relevant for likely exposure(s)?
- Were samples collected from beneath barriers that are expected to control future soil exposure risk, or to prevent groundwater impacts via leaching?
- Were lead results averaged?

Groundwater

- Were representative concentrations determined for release-related chemicals in each affected aquifer?
- Is there reason to believe that current concentrations of release-related chemicals in groundwater are only temporarily attenuated?
- Does the groundwater data have a constant mean and variance?

Vapor

- Were indoor air samples collected during worst-case conditions?
- Were indoor air samples collected from breathing zones?
- Were indoor air samples accompanied by paired samples collected from outside the occupied part of the structure?
- Were at least two rounds of paired sampling conducted?
- Were soil gas samples collected under appropriate conditions?
- Were soil gas samples collected at appropriate depths based on the source and geologic units?
- Were preferential pathways evaluated as exposure route(s) for structures that were not sampled or otherwise screened out?

Other Media

- Were representative concentrations for sediment determined analogously to those for soil?
- Were representative concentrations for surface water based on pore water samples?

3.3 Task Six: Specify Remediation Objectives

Per [IC 13-25-5-8.5\(b\)](#), a **remediation objective** is either (1) a concentration of a substance equal to the naturally occurring concentration of that substance on the site (see Section 3.3.2), or (2) an environmental concentration of a substance that is, given the conditions, uses, and restrictions prevailing on the site, protective of human health and the environment. [IC 13-25-5-8.5\(d\)](#) divides the latter category into three further types, discussed in Sections 3.3.3, 3.3.4, and 3.3.5. IDEM has determined that another type of remediation objective (see Section 3.3.6), is also acceptable due to its mathematical equivalence to those described in [IC 13-25-5-8.5\(d\)](#).

Per [IC 13-25-5-8.5\(b\)\(2\)](#), the activities taking place on the site and the expected future use of the site are essential factors to consider when choosing appropriate remediation objectives. For example, uses that include frequent and long-term occupancy by children (e.g., residences and schools) are likely to result in different exposures and levels of risks than those when exposures are relatively short-term (e.g., along a portion of a paved rail trail) or restricted to adults (e.g., in an office or factory). IDEM refers to remediation objectives that permit unrestricted use of a decision unit as **unconditional remediation objectives**.

3.3.1 Basis for Requirement

[IC 13-25-5-8.5\(a\)](#) directs responsible parties to specify remediation objectives as part of a remediation work plan. Concentration-based remediation objectives provide quantitative values against which to directly compare representative concentrations. As discussed in Section 3.3.6, remediation objectives stated in terms of the cancer risk range (for carcinogens) or hazard quotients (for non-carcinogens) are also acceptable.

3.3.2 Using Background Concentrations as Remediation Objectives

[IC 13-25-5-8.5](#) defines “background levels of hazardous substances and petroleum that occur naturally on the site” as acceptable remediation objectives. IDEM and U.S. EPA (2002e) define **naturally occurring background** as substances present in the environment in forms that have not been influenced by human activity (e.g., arsenic in New Albany shale). IDEM does not anticipate requiring a responsible party to implement a remedy to address naturally occurring concentrations of chemicals, even if those concentrations exceed IDEM's published levels.

Responsible parties that choose naturally occurring background concentrations as remediation objectives must take steps to reduce concentrations of released chemicals to levels at least as low as those that existed at the decision unit prior to any release of the same chemicals, or show that concentrations are already that low. Note that naturally occurring background concentrations *may* be substantially lower than concentrations that are protective of human health and the environment, and that achieving them may prove unnecessarily difficult and/or stringent.

IDEM anticipates that only a relatively small percentage of projects will require or benefit significantly from background demonstrations. For those that do, Appendix B provides detailed example procedures for conducting background demonstrations.

Sometimes release-related chemicals at a decision unit are from an **off-site source**. An off-site source is an identifiable, localized source outside the facility of interest that contributed release-related chemicals to the facility property (e.g., chlorinated solvents from a dry cleaner impacting a neighboring business that has no history of using those solvents). The presence of an off-site source cannot simply be asserted; it must be demonstrated. An adequate off-site source demonstration will identify the chemicals attributed to an off-site source, along with their concentrations (including any significant spatial or temporal variation) and the locations where those chemicals are coming onto the subject property. Suitable lines of evidence might include groundwater concentration gradients, surface and/or groundwater flow direction, suspected

source operating history, surface or subsurface soil sample results, prevailing wind direction, etc. Each off-site source demonstration is inherently project specific and IDEM will evaluate each demonstration on its merits. A successful off-site source demonstration shifts responsibility for the identified release to the party responsible for that release in many, but not all situations.

3.3.3 Using IDEM's Published Levels as Remediation Objectives

IC 13-25-5-8.5(d)(1) – Levels of hazardous substances and petroleum calculated by the department using standard equations and default values for particular hazardous substances or petroleum.

Risk-based remediation objectives recognize that there is a relationship between the concentration of a chemical in a particular medium to which a population is exposed and the likelihood that members of that population will suffer adverse effects. The risk-based approach to development of remediation objectives uses equations that mathematically relate toxicity data, exposure assumptions, and chemical concentrations to the risk of adverse effects, structured so that the result is a set of environmental concentrations considered acceptable *subject to the underlying assumptions*. As the underlying assumptions change, the calculated acceptable environmental concentrations also change.

Many regulatory agencies use this approach to generate tables of acceptable concentrations for chemicals in various media under specific exposure scenarios. IDEM calculates such concentrations and calls them **published levels**. In doing so, IDEM relies on data from U.S. EPA's [Regional Screening Levels \(RSL\) Tables](#) (U.S. EPA, 2021e; updated periodically) and guidance from the accompanying [Regional Screening Levels User's Guide](#) (U.S. EPA, 2021f; updated periodically). Appendix A describes the specific methods that IDEM uses to derive its published levels. Links to IDEM's published level tables appear on the [IDEM Screening and Closure Level Tables](#)²⁵ web page.

Many responsible parties choose to use IDEM's published levels as remediation objectives. This is entirely appropriate if the likely exposures in a decision unit reasonably match the assumptions embodied in IDEM's published levels. While responsible parties may find it convenient to use IDEM's published levels as remediation objectives, doing so is not required. As noted earlier, other options exist and are described in Subsections 3.3.4 through 3.3.6. There may be significant advantages to pursuing other options.

The remaining portions of Subsection 3.3.3 describe the different types of levels published by IDEM, some of the assumptions they incorporate, scenarios where their use is appropriate, and how to use them.

3.3.3.1 Using IDEM's Published Levels for Soil

Because most routine exposure to chemicals in soil occurs in the top few centimeters of the soil profile, it is important to evaluate soil exposure risk for both soil currently exposed at or near the ground surface, and also for soil that is reasonably likely to be exposed in the future. However, soil exposures and appropriate sample depths are highly dependent on present and likely future land use and conditions. For example, bare soil typically constitutes a greater exposure risk than vegetated soil. Conversely, soil under barriers may not be available for exposure for as long as the barrier remains in place.

Exposure may also occur to soil at depth. For example, gardening may result in routine exposure to soil at depths of six inches or more. Further, because soil is potentially subject to excavation, it is often important to consider soil exposure risk either to workers in contact with soil that lines excavations, or to

²⁵ From 2012 to 2021, IDEM referred to its published levels as *screening levels*, and from 2001 to 2010 as *closure levels*. Levels included in the 1994 VRP Guidance were called *Tier II* levels. The term *published level* is more general than either *screening level* or *closure level* and reflects the fact that many of IDEM's published levels may have more than one appropriate use, depending on circumstances.

persons in contact with previously excavated soil that currently resides at or near the ground surface. IDEM considers shallower soil more likely to undergo excavation than deeper soil, and that it is unlikely that soil deeper than 15 feet below ground surface will be exposed or brought to the surface. For this reason, it is not generally necessary to evaluate soil deeper than 15 feet below ground surface for soil exposure risk, unless project-specific information is available indicating that deeper excavation is likely to occur.

IDEM publishes levels for six different soil exposure scenarios. With some exceptions, IDEM's published levels for soil take into account exposure via four different routes:

- Absorbing chemicals through the skin when touching soil
- Inhaling chemicals that volatilize from soil
- Inhaling chemicals in soil particles (e.g., dust)
- Ingesting chemicals in soil

Because these exposure routes often exist simultaneously for a given receptor, IDEM's published levels combine the ingestion, inhalation, and dermal absorption routes into a single value for each of the exposure scenarios in IDEM's published levels table. Appendix A describes the procedures that IDEM uses when deriving published levels for soil.

Residential Soil

IDEM's published levels for residential soil assume that residents, *including children*, undergo frequent exposure to release-related chemicals – an assumption that generally results in the highest potential exposures and lowest published levels. IDEM's published levels for residential soil are appropriate for use in any area that does or is reasonably likely to contain occupied residences and other areas where children may be present on a daily basis (e.g., playgrounds, schools, day care facilities, and similar areas or uses). IDEM does not publish residential soil levels for some volatile chemicals, due to their rapid attenuation from exposed soil. See Section A.4.1.1 for details.

Commercial Soil

IDEM's published levels for commercial soil assume 25 years of frequent exposure to adult workers. They are appropriate for use when evaluating risk at factories, warehouses, office buildings, retail businesses, and other commercial properties. If portions of a commercial property have different exposures (e.g., a day care facility within an office complex or a strip mall), those areas warrant separate consideration and, where appropriate, different remediation objectives. IDEM does not publish commercial soil levels for some volatile chemicals, due to their rapid attenuation from exposed soil. See Section A.4.1.2 for details.

Excavation Worker Soil

IDEM's published levels for excavation worker soil assume relatively short term (45 days) exposure to adult workers. They are appropriate for use when evaluating risk to workers in contact with, or potentially in contact with soil in or from trenches and other excavations (basements, swimming pools, etc.)

Recreational Soil – Trail Scenario

IDEM's published levels for recreational trail soil are suitable for use at capped trails, such as a paved or gravel-covered multi-use path for walking, cycling, jogging, skating, and other similar activities. IDEM assumes a vegetative cover fraction of 0.99 for this scenario.

Recreational Soil – Playing Field Scenario

IDEM's published levels for recreational playing field soil are suitable for use at properties where organized sports activities occur (e.g., soccer, baseball, softball, lacrosse, football, etc.). Note that this scenario assumes an exposure frequency of thirty days and a vegetative cover fraction of 0.8 for this scenario. Project-specific circumstances may make these or other assumptions unreasonable. If so, adjust the relevant parameters and provide a rationale for doing so.

Recreational Soil – Community Park Scenario

IDEM's published levels for community park recreational soil are suitable for use at properties that may host a wide variety of recreational activities. Such properties may have picnic shelters, basketball courts, tennis courts, dog walking areas, amphitheaters, and perhaps trails, sports fields, and/or children's play areas. Because they assume greater exposures than those assumed in the trail and playing field scenarios, IDEM's published levels for the community park scenario are generally lower than those for trails or playing fields. Therefore, IDEM's published levels for the community park scenario are also protective for the trail and playing field scenarios. However, residential remediation objectives are generally better suited for playground areas where preschool children may have high daily soil contact rates. IDEM assumes a vegetative cover fraction of 0.8 for this scenario.

3.3.3.2 Using IDEM's Published Levels for Groundwater

IDEM considers both current and potential exposures when evaluating groundwater risk. Both groundwater currently in use and groundwater reasonably subject to future use should be evaluated for groundwater exposure risk.

For chemicals with maximum contaminant levels (MCLs) established under the Safe Drinking Water Act, IDEM uses those MCLs as published levels for groundwater. For other chemicals, IDEM's published levels for groundwater take into account exposure via three different routes:

- Absorbing chemicals through the skin when touching groundwater
- Inhaling chemicals that volatilize from groundwater
- Ingesting chemicals in groundwater

Because these exposure routes often exist simultaneously for a given receptor, IDEM's published levels for groundwater combine the ingestion, inhalation, and dermal absorption routes into a single value for each chemical that does not have an MCL. Appendix A describes the procedures that IDEM uses when deriving published levels for groundwater.

IDEM publishes levels only for residential groundwater exposure. IDEM does not attempt to define or publish levels for any of the many possible commercial groundwater uses. Responsible parties that wish to derive project-specific groundwater remediation objectives for commercial uses can do so, and IDEM will evaluate those proposals on their merits.

IDEM's published levels for groundwater apply to water below the ground surface, within water supply systems, or at the tap, and assume use typical of that which occurs in residences (e.g., drinking, cooking,

bathing, etc.) by both children and adults. IDEM generally considers groundwater that is below IDEM's published levels for residential groundwater to be acceptable for unrestricted use.²⁶

3.3.3.3 Using IDEM's Published Levels for Indoor Air

Indoor air exposure occurs inside occupied structures. For this reason, IDEM's published levels for indoor air are only suitable for evaluating indoor air risk. IDEM's published levels for indoor air take into account exposure via inhaling chemicals present in indoor air. IDEM publishes levels for two different indoor air exposure scenarios and defines (but does not publish) two sets of indoor air action levels that are easily derived from IDEM's published levels for indoor air. Appendix A describes the procedures that IDEM uses when deriving its published levels for indoor air exposure.

Residential Indoor Air

IDEM's published levels for residential indoor air assume 26 years of exposure, including child exposure. They are suitable for evaluating risk from long-term indoor air exposure inside residential structures. IDEM's published levels for residential indoor air are based on a subset of the residential indoor air screening levels appearing in U.S. EPA's RSL table and include only those chemicals that IDEM defines *for this purpose* as volatile.²⁷

IDEM defines the **residential indoor air action level** for a chemical as ten times that chemical's IDEM published level for residential indoor air. Residential indoor air action level exceedances warrant prompt action to reduce exposures.

Commercial Indoor Air

IDEM's published levels for commercial indoor air exposure assume 25 years of exposure to adult workers. They are suitable for evaluating risk from long-term indoor air exposure inside commercial structures. IDEM's published levels for commercial indoor air are based on a subset of the commercial indoor air screening levels appearing in U.S. EPA's RSL table and include only those chemicals that IDEM defines *for this purpose* as volatile.

IDEM defines the **commercial indoor air action level** for a chemical as ten times that chemical's IDEM published level for commercial indoor air. Commercial indoor air action level exceedances warrant prompt action to reduce exposures.

²⁶ Ecological risk from release-related chemicals in groundwater may be a concern in karst.

²⁷ Defined *for this purpose* as having a vapor pressure greater than or equal to 1 millimeter of mercury.

3.3.3.4 Using IDEM's Published Levels for Subsurface Vapor

IDEM's published levels for subsurface vapor are intended as indicators of vapor intrusion potential or, in conjunction with indoor air concentrations, as a strong line of evidence for or against actual vapor intrusion. Soil gas concentrations can drive remedy decisions even in the absence of current indoor air exceedances. IDEM publishes levels for six different soil gas scenarios. As noted in Section 2.2.6.2, IDEM generally considers shallow soil gas to include samples collected no more than five feet below ground surface, and deep soil gas samples to include samples collected more than five feet below ground surface. Appendix A describes the procedures that IDEM uses when deriving published levels for soil gas.

Table 3-A: Vapor Attenuation Factors

Medium	Building Type	Attenuation Factor	Suitable for:
Subslab soil gas	Residential or Commercial	0.03	Vapor remedy determination
	Large Commercial	0.003	
Soil gas exterior - shallow	Residential or Commercial	0.1	Delineation; investigation of indoor air in nearby structures; vapor remedy determination
	Large Commercial	0.01	
Soil gas exterior – deep	Residential or Commercial	0.03	
	Large Commercial	0.003	
Conduit vapor*	Residential or Commercial	0.03	
Crawl space air	Residential or Commercial or Large Building	1	Vapor remedy determination

*IDEM considers the 0.03 conduit vapor attenuation factor referenced in McHugh and Beckley (2018) to be a conservative value that provides a reasonable starting point for investigations. IDEM may update this attenuation factor on receipt of further research results.

3.3.3.5 Using Other Published Levels

Per [327 IAC 2-11-5\(3\)](#), surface water quality standards shall be met in the surface waters of the state at the groundwater – surface water interface. Pore water samples are technically most appropriate for this purpose. Indiana's surface water quality standards appear in [327 IAC 2-1-6](#). U.S. EPA Region 4 levels (U.S. EPA, 2018) are acceptable for those chemicals for which IDEM does not publish surface water quality standards.

Sediment intended for eventual placement on land should be evaluated against soil levels and evaluated for leaching potential using SPLP or a similar procedure. U.S. EPA Region 4 publishes ecological screening levels for many chemicals in sediment (U.S. EPA, 2018), and those levels are acceptable for use in Indiana.

3.3.4 Using Site-specific Levels as Remediation Objectives

[IC 13-25-5-8.5\(d\)\(2\)](#) – *Levels of hazardous substances and petroleum calculated using site specific data for the default values in the department's standard equations.*

IDEM has historically interpreted the term “site specific data” in [IC 13-25-5-8.5\(d\)\(2\)](#) to mean the physical and chemical characteristics of a site and associated release-related chemicals. For guidance on site-specific levels that rely on behaviors or behavior restrictions [institutional controls, installation and maintenance of engineering controls or other remedial measures, land use restrictions, etc. as defined in [IC 13-25-5-8.5\(d\)\(3\)](#)] to control risks, see Section 3.3.5.

Opportunities for derivation of site-specific levels under IDEM's historic interpretation of [IC 13-25-5-8.5\(d\)\(2\)](#) are essentially constrained by the equations that U.S. EPA and IDEM use to derive the levels that appear in their published tables (U.S. EPA, 2021e and Appendix A of this document). Those equations incorporate many different physical and chemical parameters, some of which are relatively fixed and others of which may exhibit a considerable range of values. U.S. EPA often employs parameter values at the conservative end of their observed distributions as default values when deriving screening levels. For this reason, default physical and chemical parameter values may not accurately reflect conditions for a release. Where that is the case, it *may* be worthwhile to collect site-specific data for one or more physical and/or chemical parameters and use that data in conjunction with the relevant equations to derive site-specific levels. Because of the conservative assumptions incorporated into IDEM's published levels, IDEM expects that site-specific levels derived in this way will nearly always exceed IDEM's published levels. Nevertheless, when properly derived, site-specific levels of this sort are entirely appropriate for use in evaluating potential exposure risks.

Sometimes, even large changes in a parameter value have little or no effect on the site-specific levels of a chemical. In other cases, effects may be substantial for some chemicals and negligible for others. IDEM suggests careful consideration of the potential benefits and expense of collecting site-specific data for the purpose of calculating site-specific levels. A sensitivity analysis using an iterative evaluation of the reasonable range of potential values for each parameter may prove useful. Detailed guidance on the derivation of site-specific levels using observed chemical and physical parameter values is beyond the scope of this document. See U.S. EPA (2021f) for explanation of the relevant equations and default parameter values.

Soil

The largest scope for calculation of site-specific soil levels probably relates to the inhalation risk associated with soil, specifically the volatilization factor that appears in some of U.S. EPA's soil equations. Other options include bioavailability adjustments (U.S. EPA, 2007c), levels developed under [IC 13-25-5-8.5\(d\)\(3\)](#) (Section 3.3.5), background demonstrations (Appendix B) and remediation objectives that use different target cancer risk levels (Section 3.3.6).

Groundwater

U.S. EPA's groundwater equations offer relatively few opportunities for derivation of site-specific levels based on observed chemical and physical parameters. Further, most of the chemicals that drive groundwater risk have MCLs established under the Safe Drinking Water Act. IDEM considers MCLs to be the appropriate remediation objective for water intended for human consumption, and IDEM's published levels default to MCLs where the latter exists. Therefore, most groundwater risk evaluations use IDEM's published levels for groundwater as remediation objectives, rather than site-specific levels. Other options, discussed elsewhere, include levels developed under [IC 13-25-5-8.5\(d\)\(3\)](#) (Section 3.3.5), background demonstrations (Appendix B) and remediation objectives that use different target cancer risk levels (Section 3.3.6).

Vapor

The principal opportunity for derivation of site-specific indoor air levels for current exposures under IDEM's historic interpretation of [IC 13-25-5-8.5\(d\)\(2\)](#) probably involves adjustment of vapor intrusion attenuation factors based on the special characteristics of certain large structures. It may be appropriate to adjust attenuation factors for soil gas downward by a factor of ten for certain large, open, commercial buildings that are not subdivided into smaller offices, businesses, or other spaces. Buildings that screen out of further vapor intrusion investigation and are subsequently subdivided may need re-evaluation of vapor intrusion potential. Lines of evidence that argue in favor of such adjustments include:

- *Thick foundations and excellent structural integrity.* Many commercial buildings are often slab-on-grade construction with thicker, more intact concrete slabs than residences.
- *High ceilings and large building volumes.* Ceilings are often considerably higher in commercial buildings, increasing the air volume compared to residences.
- *High air exchange rates.* Commercial buildings with high ventilation rates should experience lower indoor air concentrations if the rate of vapor intrusion from the subsurface is constant.

Other options, discussed elsewhere, include levels developed under [IC 13-25-5-8.5\(d\)\(3\)](#) (Section 3.3.5) and background demonstrations (Appendix B). Due to the inherent uncertainty associated with vapor intrusion, IDEM has determined that it is usually inappropriate to employ a target cancer risk greater than 10^{-5} when evaluating vapor intrusion risk (See Section 3.3.6 for possible exceptions).

3.3.5 Using Other Concentration-based Remediation Objectives

[IC 13-25-5-8.5\(d\)\(3\)](#) – *Levels of hazardous substances and petroleum developed based on site-specific risk assessments that take into account site-specific factors, including remedial measures, restrictive covenants, and environmental restrictive ordinances that (A) manage risk; and (B) control completed or potential exposure pathways.*

[IC 13-25-5-8.5\(d\)\(3\)](#) permits site-specific levels that take risk management strategies into account to serve as remediation objectives. Risk management strategies reduce or eliminate specific exposures through engineering controls and/or institutional controls. Engineering controls physically limit contact with, or movement of, release-related chemicals. Examples include engineered caps, slurry walls, vapor mitigation systems, sheet piling, etc. Institutional controls limit use of a property. Common institutional controls include prohibitions on residential use, limits on the extraction or use of groundwater, or restrictions on soil excavation. Environmental restrictive covenants (ERCs) or environmental restrictive ordinances (EROs) are types of institutional controls.

Because effective institutional controls or engineering controls reduce or eliminate exposure via specific exposure pathways, they increase the allowable concentrations of release-related chemicals that can be left in place. A very effective control can virtually eliminate all exposure pathways, present and reasonably likely future, from the risk evaluation, and permit product to remain in place. However, effective risk management requires an ongoing commitment to monitor, operate, and/or maintain the control *for as long as the release-related chemicals persist at levels that make the control necessary*. Ongoing commitments will vary with the nature of the control and could range from periodic inspections that monitor compliance with the terms of an ERC, all the way up to operation and maintenance of a complex engineered system. Memorializing any ongoing commitments, including operation, maintenance, and monitoring of an engineering control, in an IDEM-enforceable environmental restrictive covenant, or in an environmental restrictive ordinance²⁸ enacted by a municipal corporation, is an integral part of an effective remedy.

²⁸ Environmental restrictive ordinances apply to groundwater only.

Example: Soil contact barrier

Installation and maintenance of a physical barrier, like an engineered cap, pavement, or structure that effectively eliminates dermal contact with chemicals in soil. Note that volatile chemicals remaining under such barriers may pose a vapor exposure risk and may require other measures to adequately control risk.

Example: Limiting soil access

Maintenance of access restrictions on a parcel (e.g., a transformer enclosure where a PCB spill occurred) that effectively reduces worker access to a certain number of days per year that is significantly less than the 250 days per year assumed when IDEM calculates its published levels for commercial soil.

Example: Property-specific groundwater use restriction

A prohibition on extraction and use of groundwater found beneath a parcel, typically in conjunction with access to an alternative source of potable water.

Example: Area-wide groundwater use restriction

An environmental restrictive ordinance (see Appendix F for additional details on legal requirements associated with environmental restrictive ordinances) that prevents extraction and use of groundwater found beneath an area defined by a municipal corporation.

Example: Vapor mitigation system

Installation, maintenance, and periodic performance monitoring of an engineered system that interrupts chemical vapor transport from the subsurface into an occupied structure.

3.3.6 Using Risk Levels as Remediation Objectives

As described in Appendix A, IDEM's published levels employ a target cancer risk of 10^{-5} . However, consistent with the National Contingency Plan²⁹ and U.S. EPA, IDEM will consider proposals to use a 10^{-4} target cancer risk level for soil and groundwater:

"Generally, where a risk assessment indicates that a cumulative site risk to an individual using reasonable maximum exposure assumptions for either current or future land use exceeds the 10^{-4} lifetime excess cancer risk end of the risk range, action... is generally warranted at the site. For sites where the cumulative site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4} , action generally is not warranted, but may be warranted if a chemical specific standard that defines acceptable risk³⁰ is violated, or unless there are non-carcinogenic effects or an adverse environmental impact that warrants action. A risk manager may also decide that a lower level of risk to human health is unacceptable and that remedial action is warranted where, for example, there are uncertainties in the risk assessment results. [EPA decisions about] remedial actions taken at sites posing risks within the 10^{-4} to 10^{-6} risk range must explain why remedial action is warranted... Furthermore, the upper boundary of the risk range is not a discrete line at 10^{-4} , although EPA generally uses 10^{-4} in making risk management decisions. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions..." (U.S. EPA, 1991b)

With respect to indoor air, IDEM will in most cases use a 10^{-5} target cancer risk on a per-chemical basis to protect from exceeding 10^{-4} cumulative risk over the long term. This is because of the inherent

²⁹ 40 Code of Federal Regulations (CFR) [Section 300.430\(d\)\(1\)](#)

³⁰ Examples include MCLs, maximum contaminant level goals, or applicable or relevant and appropriate requirements.

uncertainty in measuring vapor concentrations, the fact that most indoor air measurements represent a narrow “snapshot in time”, and because access issues and the time and money expense of vapor sampling usually result in small vapor data sets. However, if indoor air sampling can be conducted in a way that addresses these uncertainties, IDEM will consider accepting chronic remediation objectives where the cumulative target risk does not exceed 10^{-4} or a hazard index of one.

Proposals to set a 10^{-4} target cancer risk as a remediation objective should use standard U.S. EPA risk assessment methodologies (U.S. EPA 1989, 1991b, 1991c, 1991d, 1992b, 1994c, 1995, 1996, 1996b, 2000b, 2002d, 2004, 2005b, 2007b, 2009b, 2011, 2014, 2021f) rather than calculating site-specific levels, as risk assessment methodologies are best suited to broad application of risk-based decision making. When proposing to use a target cancer risk of 10^{-4} , *It is not acceptable to simply multiply IDEM's published levels by ten.* Doing so ignores the fact that many carcinogenic release-related chemicals also have noncarcinogenic effects. It also ignores the potential for additive effects.

Risk-based screening and site-specific levels are usually based on chemical-specific toxic effects on an end point (target organ) or mode of action. However, people may experience simultaneous exposure to two or more chemicals that affect the same target organ or exhibit the same mode of action. When this happens, it is possible for those chemicals to produce an additive effect where exposed persons may incur a risk that exceeds a noncarcinogenic hazard quotient of 1, or a carcinogenic risk of 10^{-4} . It is also appropriate to consider the potentially additive effects of multiple chemicals in a single medium when site-specific exposure factors are integrated into the derivation of site-specific levels, or a risk characterization suggests potential risks exceeding 10^{-4} or a hazard index of 1.

Detailed guidance on evaluation of additivity is beyond the scope of this document. See U.S. EPA (2000b and 2007b) for more information on performing an evaluation of additivity. U.S. EPA's [Integrated Risk Information System](#) includes a search function that allows users to query chemicals that affect specific organs or physiological systems.

The cumulative hazard index of chemicals that affect the same target organ should not exceed 1, and the cumulative target risk of chemicals should not exceed 10^{-4} . U.S. EPA risk assessment guidance views these criteria as “points of departure”, and IDEM will generally require a remedy where these risks are exceeded.

3.3.7 How IDEM Will Evaluate Remediation Objective Specifications

General

- Are remediation objectives specified for each decision unit?
- Do specified remediation objectives include all release-related chemicals for which IDEM published levels exist?
- Are the specified remediation objectives appropriate given the activities currently taking place and reasonably likely to take place in the future in each decision unit?

Background

- For background demonstrations, are the evaluation criteria in Appendix B met?

Using IDEM's Published Levels

- If IDEM's published levels are used as remediation objectives, are those published levels from IDEM's most recent table?

Using Other Published Levels

- Are Indiana's surface water quality standards³¹ specified as remediation objectives for any surface/pore water samples?
- Are appropriate (e.g., U.S. EPA Region 4) remediation objectives specified for any sediment samples?

Site-specific Levels

- Are any proposals to employ a large building attenuation factor adjustment supported by sufficient lines of evidence?
- Are other proposed site-specific levels supported by documentation of any models, calculators, equations, parameter values, or any other inputs used to derive them, as well as outputs?

Other Concentration-based Remediation Objectives

- Do proposals to use engineering controls or institutional controls to manage risk limit exposure to acceptable levels for all relevant exposure pathways?
- If not, are unconditional remediation objectives specified for the uncontrolled pathways?

Using Risk Levels as Remediation Objectives

- Are proposed risk levels considering additivity no greater than 10^{-4} target cancer risk (generally no greater than 10^{-5} for indoor air exposures) and/or a hazard quotient of one?
- Is sufficient data available to determine with confidence that incremental cancer risk does not exceed 10^{-4} ?

³¹ [327 IAC 2-1-6](#)

3.4 Task Seven: Determine Whether a Remedy is Necessary

In the context of this guidance, a **remedy** is a means of reducing risk arising from a release-related chemical. Remedies either reduce the concentration of a release-related chemical, reduce exposure to that chemical, or both. An **adequate remedy** will reduce risks from release-related chemicals to an acceptable level.

The purpose of Task Seven is to determine whether a remedy is necessary to control unacceptable risk to human health and/or the environment that arises from a release. If no remedy is necessary, then closure without restriction or further obligation is appropriate. Otherwise, it will be necessary to select an appropriate remedy, implement it, and show that it adequately controls risk. Closure can follow a demonstration that a remedy is effective.³²

3.4.1 Basis for Requirement

Task Seven is required to determine per [IC 13-25-5-8.5\(c\)](#) whether additional action is necessary to protect human health or the environment. [IC 13-25-5-8.5\(c\)](#) states that

If the:

- (1) nature and extent of the hazardous substance or petroleum is adequately characterized under the voluntary remediation work plan, considering the remediation objectives developed under this section; and*
 - (2) the level of the hazardous substance or petroleum is demonstrated to be below:*
 - (A) background levels of the hazardous substances and petroleum that occur naturally on the site; or*
 - (B) risk levels developed under subsection (d);*
- additional action is not necessary to protect human health or the environment.*

3.4.2 Remedy Necessity Determinations: General Considerations

[IC 13-25-5-8.5\(c\)](#), strictly interpreted, calls for a simple comparison of “the level of the hazardous substance or petroleum” (what this document refers to as a representative concentration) against a remediation objective. However, IDEM recognizes the comparison should consider any relevant factors, including circumstances specific to a release or decision unit, the uncertain but often conservative nature of representative concentration determination, and the conservatism built into IDEM’s published levels (when those are used). Doing so involves judgment, and those making remedy decisions should consider various lines of evidence (Section 3.4.3) before determining a reasonable course of action.

Unless acceptable lines of evidence indicate otherwise, closure requires a remedy for all release-related chemicals that exceed unconditional remediation objectives, regardless of source. This is true even if there are multiple releases (e.g., co-mingled plumes) or a source facility has had different owners over time. Assignment of financial responsibility for controlling risk is a separate question from determining the need for such control. Responsible parties may need to negotiate or litigate among themselves regarding the financial responsibility for adequately controlling release-related risks. For example, a gas station may be ready to close its petroleum releases, but if it is also affected by chlorinated solvents that have migrated onto the station property, it may be necessary for the gas station and the source of the chlorinated solvents to negotiate requirements necessary to address those chemicals prior to closure.

Note that per [IC 13-25-5-8.5\(c\)](#), adequate characterization is a prerequisite for final remedy determinations and, by extension, closure. Section 2 of this document describes the basic requirements for characterization. However, IDEM cannot specify in advance how much work will be necessary to

³² Administrative requirements also apply.

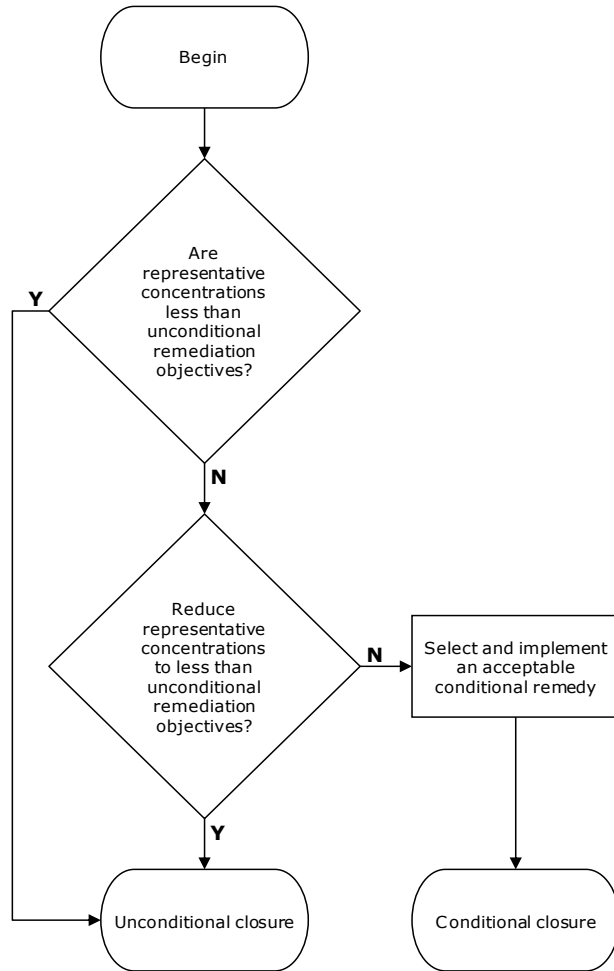
adequately characterize a release. Instead, IDEM defines the goals of characterization and will judge the adequacy of characterization efforts against those goals.

Note also that it will often be appropriate or even necessary to implement interim remedies based on preliminary characterization results. For example, if preliminary characterization data shows that residents of a structure are undergoing unacceptable exposure to vapors arising from release-related chemicals, an interim remedy to address those exposures is necessary. It is not appropriate nor protective of human health to allow such exposures to continue throughout a long characterization process. Interim remedies implemented under less pressing circumstances are also often useful and appropriate. For example, preliminary characterization may suggest that source removal or treatment will reduce the overall expense and time to closure for a project. Under such circumstances, IDEM encourages responsible parties to consider implementing interim remedies, if those remedies do not create an unacceptable hazard or worsen risks arising from a release.

Subject to the caveats noted in the preceding paragraphs, remedies will be necessary when representative concentrations of release-related chemicals in a decision unit exceed unconditional remediation objectives. A generic decision framework (also illustrated in Figure 3-A) follows.

1. Compare representative concentrations or risk levels in a decision unit against unconditional remediation objectives (most commonly, *but not necessarily*, IDEM's published levels for residential exposure scenarios).
2. If representative concentrations or risk levels in a decision unit are no greater than unconditional remediation objectives, that decision unit is eligible for closure without restrictions or future obligations. Otherwise,
3. Reduce representative concentrations or risk levels in the decision unit to levels that are no greater than unconditional remediation objectives, in which case the decision unit is eligible for closure without restrictions or future obligations, *or...*
4. Select and implement an acceptable conditional remedy.

Figure 3-A: Generic Remedy Decision Framework



3.4.3 Remedy Necessity Determinations: Lines of Evidence

A **line of evidence** is a fact or a set of facts relevant to a decision. Examples of lines of evidence include information about the chemical or physical characteristics of release-related chemicals or media, the distribution of release-related chemicals, the behavior of potential receptors, the likelihood of exposure, etc. Depending on its nature, a line of evidence can suggest that risks from release-related chemicals are either greater or lower than those assumed under standard risk evaluation approaches. However, because standard risk evaluation approaches are conservative by design, lines of evidence will often support a judgment that risks from release-related chemicals are lower than the standard approach suggests. When several lines of evidence apply to a decision unit, consider all the lines of evidence, taken together, in the decision-making process. The remainder of Section 3.4.3 discusses some lines of evidence that may apply in a decision unit. Responsible parties that wish to use lines of evidence to support remedy decisions must propose and justify them.

Current and likely future use of the decision unit

[IC 13-25-5-8.5\(b\)\(2\)\(A\)](#) states that remediation objectives shall be based in part on the “expected future use of the site”. With some exceptions, because land use changes are common (including, for example, conversion of former industrial facilities to residential use), IDEM will typically assume that future residential use is reasonably likely at most decision units³³. Exceptions include cemeteries and public roadways, and IDEM will not routinely require the use of unconditional remediation objectives or residential use restrictions as a condition of closure for cemeteries or public roadways. However, IDEM may require notice of the presence of release-related chemicals be given to the owners of cemeteries or public roadways with a graphical depiction of the nature and extent of the release-related chemicals. In cases where excavation or exposure of soil may result in unacceptable risk and future development of the property, including excavation, is likely, IDEM may require soil management plans be in place as part of the remedy, especially if the owner does not want a restriction on excavation. As part of an environmental restrictive covenant, an affirmative obligation for future owners to comply with the approved soil management plan may be necessary to adequately control exposure to release-related chemicals in soil.

Sensitive populations

Decision units routinely used by members of sensitive populations (most often children) warrant a conservative approach to risk. This is because members of those populations are often more susceptible to the adverse effects of release-related chemicals than are typical adults. For this reason, the routine and extended presence of children in a decision unit is a line of evidence favoring use of unconditional remediation objectives and less flexible application of the exceedance criteria described in [IC 13-25-5-8.5\(c\)](#).

Magnitude of exceedance

Given the conservative approaches recommended in this document for determination of representative concentrations and calculation of remediation objectives, minor exceedances of remediation objectives in a decision unit are not likely to result in unacceptable risk. For example, a single exceedance amongst an array of much lower sample results is unlikely to accurately reflect the risk of exposure to that chemical. It is not possible to define what constitutes a “minor” exceedance; the acceptable amount will vary according to other lines of evidence. For example, if receptors are known to congregate in or disproportionately use the area of the decision unit with the minor exceedance, that fact should be

³³ Assuming future residential use is not appropriate for petroleum leaking UST sites with corrective action costs that are eligible for reimbursement from the ELTF, as [328 IAC 1-3-1.3\(b\)\(5\)](#) states that, one criterion that IDEM must consider, as part of the determination of whether a corrective action plan is cost effective is “whether the remediation objectives as set forth in the approved CAP are sufficient, but no more stringent than necessary, for the current land use for the site.”

considered when considering the importance of the exceedance. On the other hand, a larger exceedance may represent a risk requiring a remedy, even if users of the decision unit do not congregate in, or disproportionately use, the area of the decision unit with the exceedance.

Number of exceedances

Sometimes a few (relative to the total sample size) minor exceedances are mixed in with a larger number of samples that are below an unconditional remediation objective. In such cases, the decision unit may not necessarily warrant a remedy. Typically, it won't be obvious that the exceedances are in a clear minority unless there are also enough samples (at least eight, and preferably more) to calculate an upper confidence limit of the mean (UCL), which is often IDEM's preferred approach. However, meaningful UCLs are dependent on either random or systematic sampling, or sufficient samples to ensure adequate coverage of the decision unit. A UCL that is below an unconditional remediation objective indicates that a remedy is not necessary for that chemical. A UCL that significantly exceeds an unconditional remediation objective means that a remedy is necessary unless the responsible party advances compelling lines of evidence that show otherwise. IDEM will evaluate such proposals on their merits.

Spatially grouped exceedances

Spatially grouped exceedances of an unconditional remediation objective may suggest the presence of a release, and usually means that a remedy is warranted, at least for the part of the decision unit where the exceedances occur. One option is to segregate the spatially grouped exceedances into a separate decision unit, and the remainder of the sample results into another decision unit. This approach may reduce the scope and expense of any necessary remedy.

Nature of potential health effect

Potential health effects from exposure to release-related chemicals fall into two categories: carcinogenic effects, and non-carcinogenic effects. A given chemical may have either type of effect, or both. Levels published by U.S. EPA and IDEM typically assume that non-carcinogenic effects, if any, are binary - that is, they either occur, or they don't - at some concentration that is at least as high as, and often much higher than, the IDEM published level. Because of the conservative approach typically used to derive non-carcinogenic levels, the concentration at which an effect may occur is likely to be considerably higher than the IDEM published level. Possible arguments in favor of relaxing a non-carcinogenic remediation objective might include the degree of conservatism employed in its derivation, the existence of new toxicological data that shows the chemical is less toxic than previously thought, or characteristics of the decision unit or potentially exposed population. However, IDEM does not have the resources to evaluate arguments that a remediation objective based on a non-carcinogenic effect should be increased because of toxicity or population considerations, and in most cases will reject proposals to evaluate such arguments.

There is sometimes more flexibility with respect to IDEM's published levels for chemicals with carcinogenic effects. When calculating published levels based on carcinogenic risk, U.S. EPA and IDEM assume that there is at least some risk for any non-zero exposure, with risk increasing in direct proportion to exposure concentration. Because IDEM calculates its published levels using a 10^{-5} target cancer risk, and a remedy is generally not warranted for cancer risks less than 10^{-4} , there is some flexibility in the application of IDEM's published levels based on carcinogenic risk. Note, however, that due to typically small sample sizes and the inherent variability of vapor sample results, IDEM is generally reluctant to move away from the 10^{-5} target cancer risk when evaluating indoor air risk.

Soil: Depth

IDEM considers it generally unlikely that excavations will extend deeper than 15 feet below ground surface and does not typically require evaluation of deeper soil for soil exposure risk. Of course, deeper

excavations do sometimes occur, and if there is reason to believe that deeper excavations are likely within a decision unit, that information should be incorporated into the decision-making process.

Soil: Persistence of release-related chemical(s)

Some chemicals are highly persistent, even in exposed media, and are likely to remain available for exposure virtually forever. Conversely, some chemicals may attenuate rapidly in *exposed* soil. For example, volatile organics are unlikely to remain for long in the top few centimeters of the soil profile, where soil exposure is most likely to occur. This is because various phenomena (volatilization, leaching, biodegradation, etc.) generally act quickly to attenuate concentrations of those chemicals in exposed soil. Yet the equations that IDEM uses to calculate its published levels for soil assume years of exposure in the residential and commercial scenarios. Because volatile chemicals in exposed soil are especially prone to attenuation, IDEM does not publish residential or commercial soil levels for chemicals with vapor pressures equal to or greater than one millimeter of mercury at standard conditions, nor does it require delineation of those chemicals for purposes of evaluating long-term soil exposure risk³⁴.

Soil: Existing cover

Release-related chemicals in soil that are underneath certain types of barriers are not available for routine soil exposure and may also undergo substantially less leaching to groundwater. If the existing cover is likely to remain in place for at least as long as the likely residence time of the release-related chemical, then the likelihood of routine soil exposure is significantly reduced. Examples of such barriers might include impervious public roadways, parking lots, engineered caps, or the footprints of buildings reasonably likely to remain in place for as long as the release-related chemicals are likely to persist. If release-related chemicals are likely to persist indefinitely at concentrations greater than unconditional remediation objectives, then a remedy such as maintenance of the existing cover or a soil management plan is likely necessary, depending on other lines of evidence that apply to the decision unit.

Groundwater: Depth to Groundwater

Sometimes dissolved release-related chemicals at concentrations greater than unconditional remediation objectives are confined to groundwater that is close to the ground surface. [312 IAC 13-4-1\(c\)](#) states that wells "...must be cased to a depth of at least twenty-five (25) feet below ground surface unless otherwise approved...", and [312 IAC 13-3-2\(a\)\(2\)\(B\)](#) states that wells shall be located as far as practicable from any known contamination source. IDEM recognizes that compliance with these rules (or any other rule) is not universal, and that it is possible for release-related chemicals in shallow groundwater to be drawn downward by active pumping. The extent to which such downward movement is likely to result in an exceedance of a remediation objective in extracted groundwater is necessarily project-specific, and depends on factors such as the concentration of the release-related chemical in the upper water bearing unit, the effectiveness of any aquitards that may impede vertical movement, and the likely dilution that would occur during downward movement. Nevertheless, the rules in [312 IAC 13](#) comprise a line of evidence relevant to decision making for release-related chemicals in groundwater.

Groundwater: Productivity of Water-Bearing Unit

Some water-bearing units may not yield enough water to be useful for drinking water wells, or yield water with excessive dissolved solids.³⁵ If release-related chemicals in groundwater are confined to formations that do not contain or produce sufficient water to be useful, or formations with excessive dissolved solids,

³⁴ Characterization of volatile chemicals and evaluation of risk associated with those chemicals is still necessary for other exposure scenarios, including the excavation worker scenario.

³⁵ [327 IAC 2-11-4](#) defines groundwater yielding less than 200 gallons per day, or containing more than 10,000 milligrams per liter of dissolved solids, as potentially qualifying for designation as limited use.

this is a line of evidence suggesting that exposure to those chemicals via installation and use of drinking water wells in that water-bearing unit is unlikely. Application of this line of evidence must consider the possibility that chemicals in the unproductive water-bearing units may move to a deeper aquifer. Such vertical movement is expected, and additional lines of evidence should be provided to demonstrate that the movement of the chemicals will not result in an exceedance of a relevant remediation objective in an aquifer. Without a convincing demonstration of limited vertical extent, a remedy will typically be warranted to address that potential risk.

Groundwater: Aquitards

There are instances in which aquitards largely separate release-related chemicals in shallow groundwater from deeper aquifers. In such circumstances, it may be possible to show that wells screened in deeper aquifers are unlikely to be significantly impacted by release-related chemicals in shallow aquifers. IDEM (2021b) describes, among other things, how to investigate the effectiveness of aquitards as barriers to chemical transport.

Groundwater: Persistence of release-related chemical(s)

Several factors influence how long release-related chemicals will remain in groundwater at concentrations above unconditional remediation objectives. These include characteristics of the release-related chemicals, the saturated soil medium, and groundwater. For example, a small release of a highly soluble chemical into a large, fast flowing aquifer may attenuate to acceptable levels in much less time than the exposure durations assumed when calculating groundwater remediation objectives. Conversely, some chemicals are known to persist in groundwater for decades (at least) when conditions do not favor attenuation.

Groundwater: Plume Behavior

Plume behavior is a key component of both characterization and groundwater remedy decisions. Expanding plumes may move into previously unaffected decision units, thus making a remedy in those units necessary. Conversely, a shrinking plume may mean that one or more decision units no longer need a remedy after a time. Other behaviors are possible – for example, no discernable trend, a reasonably steady-state flow toward some ultimate destination like a surface water body, or variable flow direction caused by nearby intermittent pumping or some other phenomenon. All these behaviors constitute potential lines of evidence relevant to remedy decisions.

Vapor: Size of data sets

Experience has shown that vapor concentrations, particularly indoor air vapor concentrations, can vary dramatically over time for many reasons. This reduces the level of certainty associated with vapor remedy decisions relative to those made for other media. This is particularly true when, as is often the case, making vapor remedy decisions using a small data set. Therefore, IDEM will be reluctant to make vapor remedy decisions based on a single set of sample results, unless the decision is to take immediate action to implement a remedy. For the same reasons, IDEM will not typically agree with proposals to derive vapor remediation objectives based on a target cancer risk of 10^{-4} unless the available data set is relatively large.

Commonly proposed lines of evidence that are weak or inadequate when used alone

Availability of water from a public supply does not mean that persons in the service area are using that public supply, or that they will not install drinking water wells in the future.

The absence of wells in the Indiana Department of Natural Resources (IDNR) Water Well Database does not mean that drinking water exposure is not occurring. Though a very useful resource, the IDNR Water Well Database is not complete. There are many wells that do not appear in the database.

Ordinances that prohibit installation of new drinking water wells may not necessarily prohibit the continued use of existing drinking water wells and may not adequately address risks from releases to groundwater.

3.4.4 Deciding Whether a Remedy is Necessary for Soil Exposure

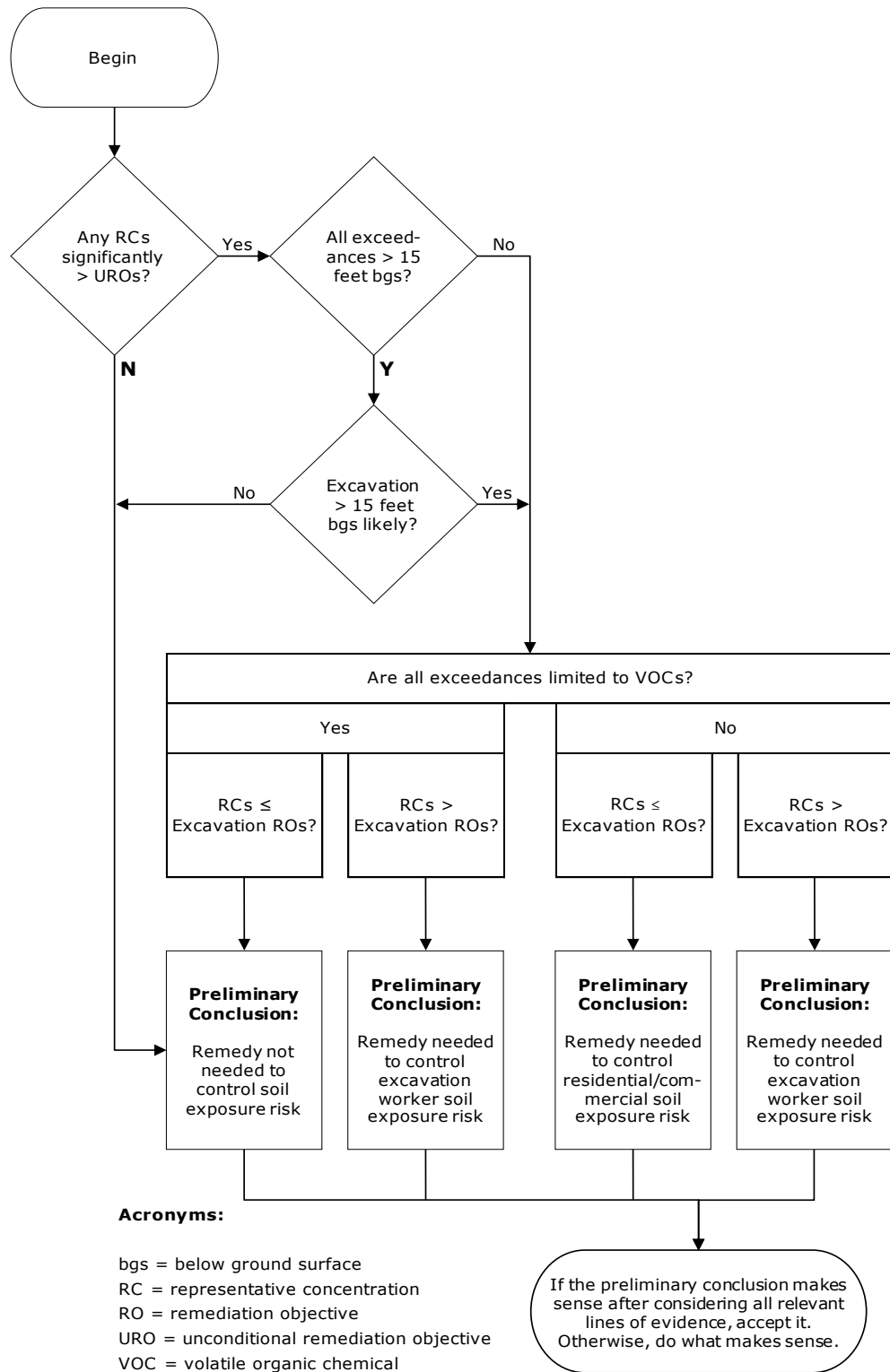
Soil remedies may control exposure risks arising directly from soil, indirect risks (release-related chemicals in soils as a source of release-related chemicals in groundwater or vapor), or both. Risks arising directly from chemicals in soil include dermal exposure to chemicals in soil, exposure to chemicals in dust and chemical vapors arising from soil, and ingestion of chemicals in soil. For direct risk, the simplest approach to deciding whether a remedy is necessary is to compare representative concentrations of release-related chemicals in the soil of a decision unit to an unconditional remediation objective. If one or more representative concentrations exceed their unconditional remediation objectives, then a remedy is usually necessary. However, as noted earlier (Section 3.4.3), IDEM recognizes several lines of evidence that may allow for some deviation from strict application of that decision criterion.

3.4.4.1 Soil Exposure Remedy Decision Key

1. Are any representative concentrations significantly above their unconditional remediation objectives?
Yes: Go to 2.
No: Preliminary conclusion: A remedy *is not* necessary for soil exposure. Go to 7.
2. Are all the exceedances in soil deeper than 15 feet below ground surface?
Yes: Go to 3.
No: Go to 4.
3. Is excavation deeper than 15 feet below ground surface reasonably likely?
Yes: Go to 4.
No: Preliminary conclusion: A remedy *is not* necessary for soil exposure. Go to 7.
4. Are all exceedances limited to volatile organic chemicals?³⁶
Yes: Go to 5.
No: Go to 6.
5. Are representative concentrations less than or equal to excavation worker remediation objectives?
Yes: Preliminary conclusion: A remedy *is not* necessary for soil exposure. Go to 7.
No: Preliminary conclusion: A remedy *is* necessary for excavation worker risk. Go to 7.
6. Are representative concentrations less than or equal to excavation worker remediation objectives?
Yes: Preliminary conclusion: A remedy *is* necessary for soil exposure. Go to 7.
No: Preliminary conclusion: A remedy *is* necessary for residential and/or commercial soil exposure risk *and* excavation worker risk. Go to 7.
7. Considering all relevant lines of evidence, does the preliminary conclusion reached above make sense for the decision unit?
Yes: Accept the preliminary conclusion. Go to 8.
No: Consider collecting additional data that will support a decision and return to step 1 above, or advance arguments in favor of a different conclusion. Go to 8.
8. Proceed to evaluation of other risks, if relevant.

³⁶ Defined for this purpose as having a vapor pressure equal to or greater than one millimeter of mercury.

Figure 3-B: Soil Exposure Remedy Decision Tree



3.4.4.2 Selected Soil Exposure Remedy Decision Scenarios

The discussion that follows describes some common soil exposure remedy decision scenarios and discusses possible approaches to deciding whether a soil exposure remedy is necessary. Remedy decisions are not always obvious. In many instances, it is necessary to consider multiple lines of evidence before deciding. Some of those lines of evidence may point in different directions and balancing those indications to arrive at a reasonable conclusion requires judgment.

The examples that follow are presented as illustrations and not as a complete survey of acceptable approaches. Other approaches may be possible and, in some cases, preferable. IDEM will evaluate other approaches on their merits.

Spatially grouped exceedances

Figure 3-C below represents a plan view of a decision unit, where the numbers in the rectangle are soil sample results within that decision unit, expressed as multiples of an unconditional remediation objective. There are several exceedances in the upper left portion of the decision unit. One of the exceedances is clearly significant. Using the highest observed concentration within the decision unit as its representative concentration would result in a determination that the entire decision unit requires a remedy. Even a representative concentration calculated as the ProUCL-recommended upper confidence limit of the mean (UCL) of all sample results in the decision unit is more than twice the unconditional remediation objective. If that UCL were used as a representative concentration for the decision unit, the entire decision unit would need a remedy.

However, the spatially grouped nature of the exceedances suggests another possible approach, which is to subdivide the decision unit into two separate decision units, and then evaluate each separately. Figure 3-D, shown below, illustrates this approach using the same data set. Under this approach, the shaded area in Figure 3-D represents the first of two newly defined decision units. In this example, only the shaded area would require a remedy. The second decision unit, represented by the unshaded area, would not require a remedy.

Figure 3-C

1.2	1.2	0.6	0.4	0.4
6	0.4	0.5	0.7	0.3
1.1	1.3	0.7	0.5	0.2
0.8	0.6	0.4	0.3	0.4

Figure 3-D

1.2	1.2	0.6	0.4	0.4
6	0.4	0.5	0.7	0.3
1.1	1.3	0.7	0.5	0.2
0.8	0.6	0.4	0.3	0.4

Subdivision of decision units is not required. For example, if a responsible party intends to pursue closure of the decision unit(s) by relying on institutional controls, it may not be worthwhile to subdivide decision units. If remedies adequately control risks, responsible parties are free to make those determinations and propose the solution for IDEM's review.

Isolated exceedances

Sometimes a systematically sampled decision unit contains a single significant exceedance amongst a number of other results that are below their unconditional remediation objectives. The simplest approach is to treat the highest observed concentration within a decision unit as the representative concentration for that chemical, and to use that highest concentration for comparison against the appropriate unconditional remediation objective. However, unless receptors spend a disproportionate amount of time in the portion of the decision unit with the exceedance, this approach will overestimate exposure and risk over the entire decision unit.

Other approaches may be applicable, depending on circumstances. The rectangles in Figures 3-E and 3-F represent plan views of decision units, where systematic sample results appear as multiples of an unconditional remediation objective. The decision unit in Figure 3-E contains a single exceedance. The other sample results are low enough to drive the ProUCL-recommended UCL (0.9) below the unconditional remediation objective. This suggests that decision unit in Figure 3-E does not require a remedy, assuming that receptors do not concentrate their time in the vicinity of the exceedance, and that the exceedance is not part of a hitherto undiscovered and significant release.

Figure 3-E

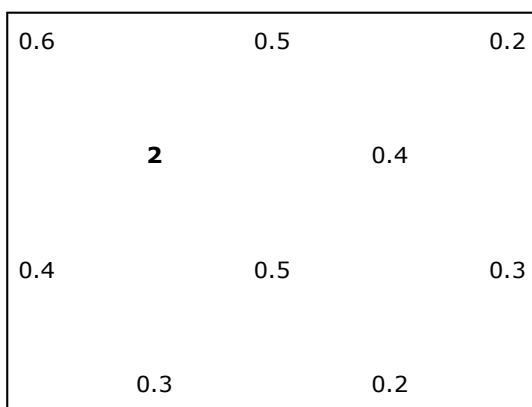
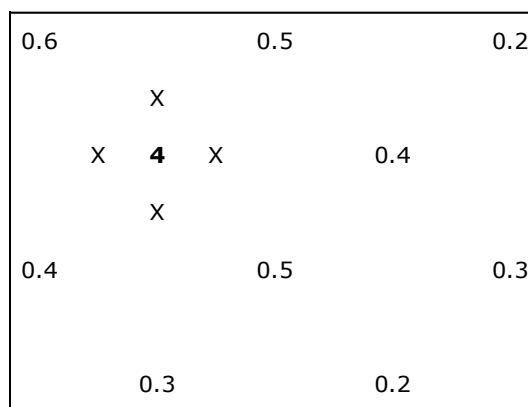


Figure 3-F



In Figure 3-F, the ProUCL-recommended UCL exceeds the unconditional remediation objective, suggesting that this decision unit requires a remedy. An alternative approach would be to undertake a focused evaluation of the area of the decision unit that surrounds the exceedance. Typically, this involves *stepping out* from the exceedance, by collecting additional samples from the area immediately surrounding the original exceedance. Figure 3-F shows four potential step out sampling locations, each depicted as an "X", located some distance in one of the cardinal directions from the original exceedance. Step outs should continue until the results show that the extent of any release is fully defined. Results from the step out samples can be pooled with the original data set prior to recalculating a new UCL for the entire decision unit or used to define a second decision unit that lies within the original decision unit and requires a remedy.

Multiple scattered exceedances in a large sample set make the remedy decision process more complicated. Options include applying a remedy to the entire decision unit; using step out procedures to define and separately evaluate portions of the original decision unit, or where the sample array or design makes it appropriate to do so, calculating a UCL for the entire sample set and comparing that UCL to the unconditional remediation objective.

Exceedance under a barrier

Per [IC 13-25-5-8.5\(c\)](#), adequate characterization is a prerequisite for final remedy determinations and, by extension, closure. For this reason, it is not acceptable to propose a pre-emptive soil exposure remedy (such as maintenance of a barrier) *in lieu of* characterizing soil underneath barriers that may currently control soil direct exposure.

Sample design and results interpretation should focus on likely risks should the barrier no longer exist. In most cases, this will involve collecting soil samples from beneath the barrier as if the barrier did not exist and treating the soil layer immediately beneath the barrier as the potential future soil surface.

Note that relatively impermeable barriers can significantly impede leaching of release-related chemicals from vadose zone soil to groundwater. Where this is the case, barrier removal may result in, or increase the magnitude of, release-related chemicals in groundwater, perhaps at concentrations that require a groundwater remedy. Section 2.2.4 describes approaches to evaluating the leaching potential of release-related chemicals in vadose zone soil.

Using levels that presume a remedy

IDEM's published levels for residential soil are one acceptable type of unconditional remediation objective. IDEM also publishes several types of soil levels that incorporate, as part of their derivation, specific restrictive assumptions regarding types and durations of exposures. For example, IDEM's published levels for commercial soil assume adults-only exposure, while IDEM's published levels for recreational soil include child exposure, but at much lower frequencies and durations than those assumed when calculating residential soil levels. For these reasons, *use of IDEM's published levels for commercial and/or recreational soil is appropriate only when a remedy that restricts certain uses is either anticipated or in place.*

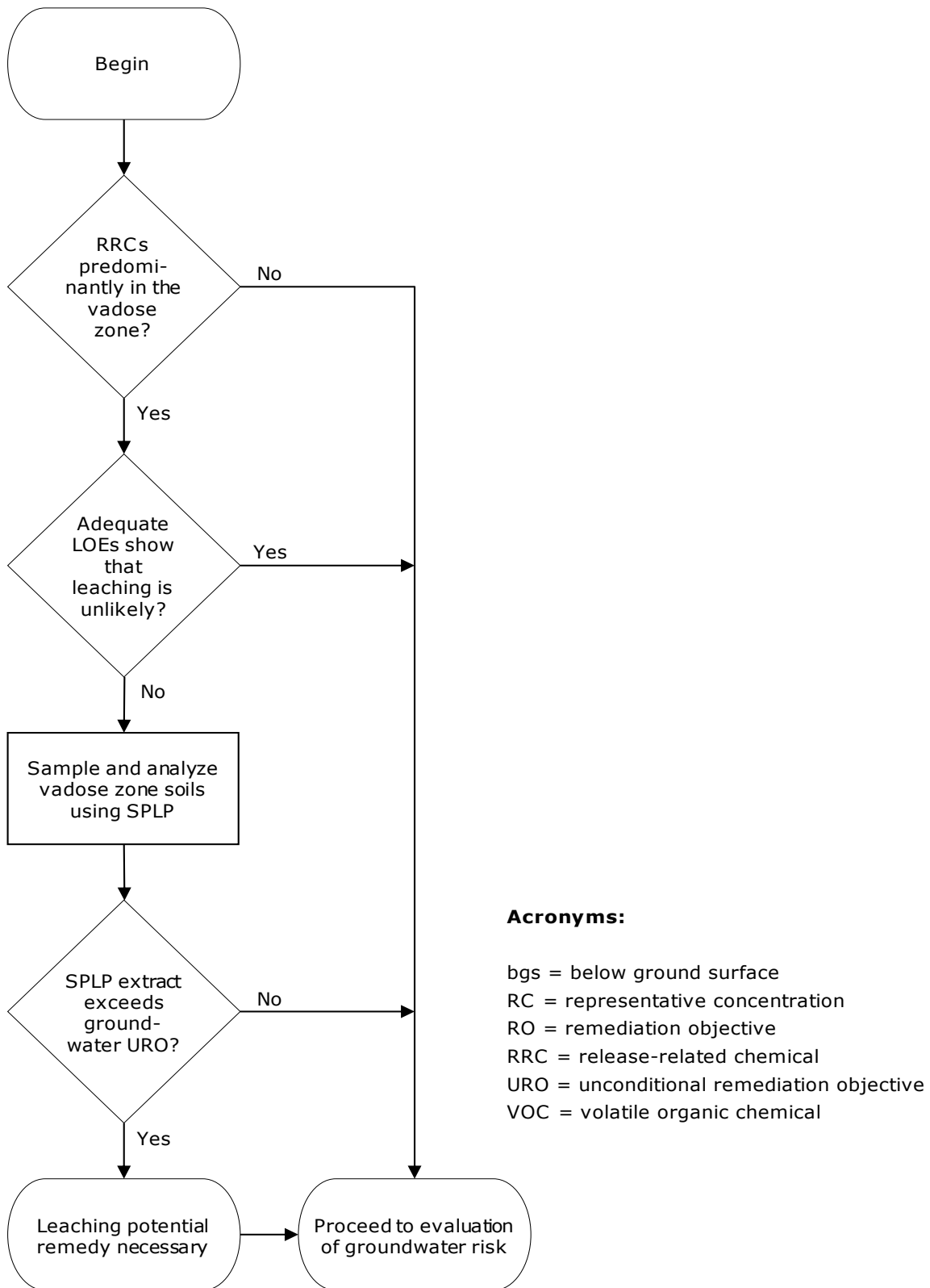
3.4.5 Deciding Whether a Remedy is Necessary for Leaching Potential

Some chemicals released to soil may subsequently move downward through the soil profile (leach) and reach groundwater. If groundwater concentrations of leached chemicals subsequently exceed unconditional remediation objectives, a remedy is typically necessary. Depending on circumstances, adequate remedies may need to address release-related chemicals in soil, or groundwater, or both. Even if groundwater already exceeds unconditional remediation objectives, chemicals currently bound to soil may leach, either contributing to the ongoing groundwater problem, or making it worse.

3.4.5.1 Leaching Potential Remedy Decision Key

1. Are release-related chemical concentrations highest in the vadose zone?
Yes: Go to 2.
No: Go to 5.
2. Do adequate lines of evidence (Section 3.4.5.2) show that leaching of release-related chemicals to groundwater is unlikely?
Yes: Go to 5.
No: Go to 3.
3. Sample and analyze vadose zone soil using synthetic precipitation leaching procedure, or similar technique. Go to 4.
4. Do any of the SPLP extracts exceed unconditional groundwater remediation objectives?
Yes: A leaching potential remedy is necessary. Go to 5.
No: Go to 5.
5. Proceed to evaluation of groundwater exposure risk.

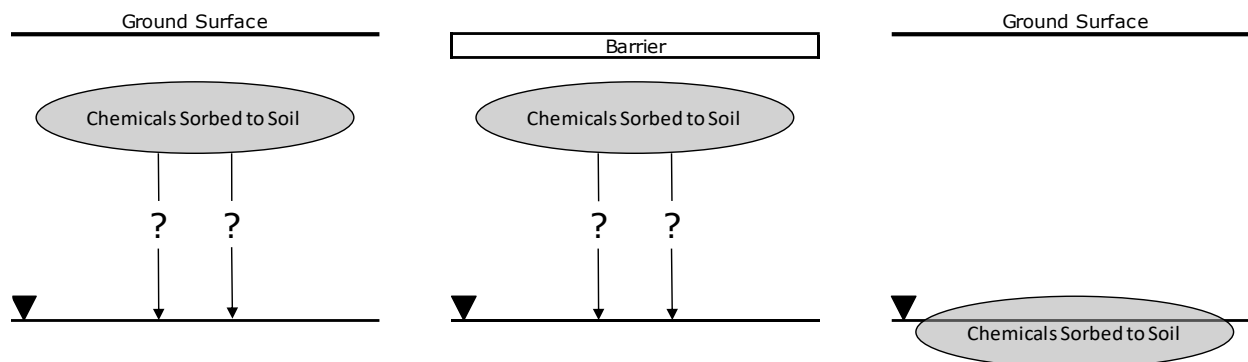
Figure 3-G: Leaching Potential Remedy Decision Tree



3.4.5.2 Selected Leaching Potential Remedy Decision Scenarios

Figure 3-H (below) depicts, in profile view, three common leaching potential scenarios. Each is discussed separately below, though they can also occur in combinations. The examples that follow are presented as illustrations and not as a complete survey of acceptable approaches. Other approaches may be possible and, in some cases, preferable. IDEM will evaluate other approaches on their merits.

Figure 3-H: Three Common Leaching Potential Scenarios



The leftmost scenario depicts release-related chemicals in the vadose zone, where those chemicals are subject to infiltrating precipitation. In this scenario, chemicals may or may not leach downward and cause groundwater to exceed an unconditional remediation objective. Whether they do so depends on many factors, including the concentrations and characteristics of the released chemicals, the properties of the soil column, depth to groundwater, amount of precipitation, and elapsed time since the release. It may be possible to demonstrate through various lines of evidence that vadose zone chemicals are unlikely to cause unacceptable risk in groundwater. For example, if release-related chemicals in the vadose zone have been subject to leaching for an extended period, yet have not caused an exceedance of unconditional groundwater remediation objectives, it may be possible to argue that they are unlikely to do so in the future.

However, the most straightforward way to determine whether or not a remedy is necessary for vadose zone soil in the leaching potential scenario is to collect samples of vadose zone soil containing the highest concentrations of release-related chemicals, and subject those samples to the synthetic precipitation leaching procedure (SPLP). If the leachate produced by SPLP exceeds an unconditional groundwater remediation objective, a soil remedy is necessary for the leaching potential scenario. If groundwater sampling shows that one or more release-related chemicals already exceed an unconditional groundwater remediation objective, then leaching or direct transport to groundwater has already occurred, and a groundwater remedy is also necessary.

The middle scenario is similar, except that there is a relatively impermeable barrier above the chemicals that eliminates or greatly reduces precipitation infiltration. Examples of such barriers include structures, pavement, or engineered caps. In this case, IDEM recommends SPLP as the most straightforward way to determine whether a remedy is necessary for vadose zone soil in the leaching potential scenario.

As noted earlier, [IC 13-25-5-8.5\(c\)](#) requires adequate characterization as a prerequisite for final remedy determinations and, by extension, closure. For this reason, it is not acceptable to propose maintenance of a barrier as a pre-emptive leaching potential remedy *in lieu of* characterizing soil underneath barriers that may currently control precipitation infiltration. As before, if groundwater sampling shows that one or more release-related chemicals already exceed an unconditional groundwater remediation objective, then

leaching or direct transport to groundwater has already occurred, and a groundwater remedy is also necessary.

The rightmost scenario depicts the instance in which release-related chemicals have already leached to, and are in relatively continuous contact with, groundwater. The focus in this instance should be on sampling groundwater. If an exceedance of an unconditional groundwater remediation objective is going to occur, this is the most likely circumstance for it to do so. If groundwater sampling shows that one or more release-related chemicals exceed an unconditional groundwater remediation objective, then a groundwater remedy is necessary.

3.4.6 Deciding Whether a Remedy is Necessary for Groundwater Exposure

Groundwater exposure risk includes risks arising from drinking and touching release-related chemicals in groundwater, and from breathing release-related chemicals that volatilize from groundwater that is used inside structures. IDEM will generally assume, unless convincing lines of evidence suggest otherwise, that release-related chemicals exceeding unconditional remediation objectives in any water from below the ground surface *may* pose a groundwater exposure risk. IDEM will not limit groundwater exposure risk evaluations to water issuing from a tap. Indirect groundwater risks occur mostly when release-related chemicals in groundwater volatilize in the subsurface and enter structures via vapor intrusion.

Other groundwater risk scenarios are less common or highly project specific. Examples include uptake of chemicals in irrigation water by plants or domestic animals, or risks associated with chemicals in groundwater used as part of a specific industrial process. The universe of possible exposure scenarios is so vast and variable that IDEM only publishes levels for residential groundwater and considers them an acceptable form of unconditional remediation objective. Risk evaluations that include other groundwater exposure scenarios are necessarily project-specific and beyond the scope of this document. IDEM will review such evaluations on their merits.

Because groundwater flows, it can serve as a transport mechanism for dissolved (and sometimes suspended) release-related chemicals, so that the area(s) requiring a groundwater remedy may change over time. This fact complicates groundwater remedy decisions and makes it necessary to ask not just where release-related chemicals are in groundwater today, but also where they might be in the future.

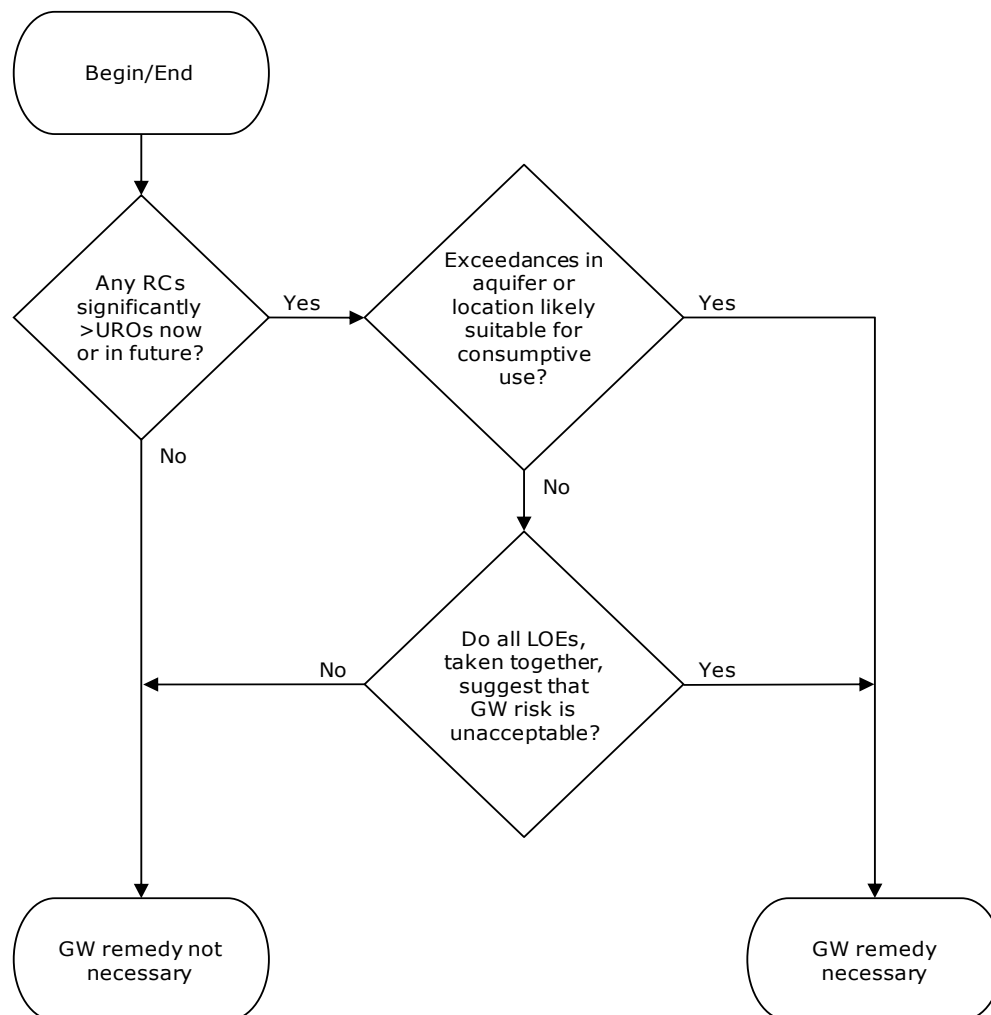
IDEM acknowledges that it is rarely possible to precisely determine in advance the ultimate extents of release-related chemicals in groundwater. Nevertheless, adequate control of groundwater risk usually requires a remedy in areas reasonably likely to exceed unconditional remediation objectives.

For groundwater exposure risk, the simplest approach to deciding whether a remedy is necessary is to compare present and reasonably likely future representative concentrations of release-related chemicals in the groundwater of a decision unit to their unconditional remediation objectives. If one or more representative concentrations exceed their unconditional remediation objectives, then a remedy is usually necessary. However, as stated earlier, IDEM recognizes several lines of evidence (Section 3.4.3) that may allow for some deviation from this decision criterion.

3.4.6.1 Groundwater Remedy Decision Key

1. Do any representative concentrations of groundwater in the decision unit significantly exceed their unconditional remediation objectives and/or appear reasonably likely to do so in the future?
Yes: Go to 2.
No: Go to 4.
2. Are any representative concentrations in the decision unit that significantly exceed their unconditional remediation objectives located in an aquifer or location that is reasonably likely to be suitable for consumptive purposes?
Yes: Preliminary conclusion: A remedy *is* necessary for groundwater. Go to 3.
No: Preliminary conclusion: A remedy *is not* necessary for groundwater. Go to 3.
3. Considering all available lines of evidence (Section 3.4.6.2), does the preliminary conclusion reached above make sense for the decision unit?
Yes: Accept the preliminary conclusion. Go to 5.
No: Collect additional data that will support a decision and return to step 1, or reject the preliminary conclusion. Go to 5.
4. The decision unit does not need a remedy for groundwater. Go to 5.
5. Continue with evaluation of other exposure scenarios.

Figure 3-I: Groundwater Remedy Decision Tree



Acronyms:

GW = groundwater
LOE = line of evidence
RC = representative concentration
URO = unconditional remediation objective

3.4.6.2 Selected Groundwater Remedy Decision Scenarios

The discussion that follows describes some common groundwater remedy decision scenarios and discusses possible approaches to deciding whether a remedy is necessary for these scenarios. It does not include all possible scenarios. Remedy decisions are not always obvious. In many instances, it is necessary to consider multiple lines of evidence before deciding. Some of those lines of evidence may point in different directions, and balancing those indications to arrive at a reasonable conclusion requires judgment.

Sporadic exceedances

Sometimes large groundwater data sets collected over several quarters or even years at multiple locations include a single exceedance, or a number of exceedances that is small relative to the size of the overall data set. Sometimes there are plausible explanations for occasional exceedances (e.g., change in groundwater elevation, sampling/handling/laboratory issues, etc.). The reasons for occasional minor exceedances become important if the risk from the exceedances is unacceptable and an active remedy is proposed. But in every case, it is important to decide whether such exceedances warrant a remedy. Important lines of evidence to consider in this decision include:

- How large is/are the exceedance(s) relative to the unconditional remediation objective?
- How frequently do they occur?
- Does that frequency appear to be diminishing or increasing?

When deciding whether a remedy is necessary, keep in mind that unconditional groundwater remediation objectives assume many years of exposure, and that minor short-term exceedances may be acceptable. Another option, when there are at least eight quarters of data available, is to calculate a UCL for each of the release-related chemical(s) of concern that appear in each well and compare them against appropriate unconditional groundwater remediation objectives.

Persistent exceedance at the edge of a sampling array

This circumstance suggests the need for further investigation. The exceedance may be part of a separate plume, or an indication that delineation of the initial plume is not complete.

Exceedances trending downward

Sometimes observed concentrations show a clear downward trend. However, even if projection of that trend shows that concentrations are likely to quickly drop below unconditional remediation objectives, IDEM will require a remedy unless convincing lines of evidence suggest otherwise. The reason for this is that projections are frequently inaccurate. Concentrations trends may plateau at levels above the unconditional remediation objective, or they may even rebound and move higher. Even if concentrations do eventually fall below the unconditional remediation objective, unacceptable exposure may occur during the intervening period.

Exceedances trending upward

In the absence of compelling lines of evidence to the contrary, this circumstance requires a remedy.

Chemicals that degrade into something more toxic

Several different processes may act on released organic chemicals and transform them into different chemicals. IDEM will require a remedy for degradation products that exceed unconditional remediation objectives, even if those products were not part of the original release. Sometimes the products of degradation processes are more toxic than the original chemicals. The most common instance of this is

the generation of vinyl chloride via reductive dechlorination. IDEM's published level for vinyl chloride is lower than that of its common precursor chemicals (e.g., tetrachloroethene and trichloroethene).

Seasonal variation in concentration or variation with depth to groundwater

Depending on circumstances, concentrations of release-related chemicals may vary directly or inversely with groundwater elevation. For example, concentrations may consistently spike during springtime monitoring events when groundwater is often elevated and be below unconditional remediation objectives during other seasons. The magnitude or duration of any such exceedance is extremely difficult to predict with confidence, and a quarterly groundwater monitoring event may be the only data point collected during a six-month period. For these reasons, IDEM has determined that seasonal exceedances are of greater concern than less frequent, sporadic exceedances, and in the absence of compelling lines of evidence to the contrary, will require a remedy under these circumstances.

Confined to aquifers of limited utility

Dissolved release-related chemicals are sometimes confined to areas or aquifers of limited utility for consumptive purposes. Examples of this include aquifers that are very close to the ground surface, aquifers that yield very little water, and/or groundwater in areas subject to uses that make them unlikely locations (e.g., roadways, cemeteries) for future drinking water wells.³⁷ Section 3.4.3 describes some lines of evidence that may be relevant to aquifers of potentially limited utility.

However, because groundwater flows, and because every release is *some* finite distance from an existing or potential well, it is important to consider the likely fate of release-related chemicals dissolved in groundwater. For example, chemicals that degrade readily in conditions that occur around a release are less likely than more persistent chemicals to reach a well at unacceptable concentrations. The density of release-related chemicals, their concentrations, the existence and effectiveness of any aquitards, and the likely attenuation that would occur during transport are all important considerations. In some locations active pumping of groundwater may draw dissolved chemicals laterally or downward.

There is no fixed recipe for making decisions in these situations. Each is inherently project-specific, and the final decision will inevitably involve weighing the relative importance of available lines of evidence.

Exceedance in a wellhead protection area

Wellhead protection areas are delineated by a specific groundwater time of travel interval (typically five years) or, in some cases, a fixed 3,000 foot radius originating at one or more public water supply wells. Because wellhead protection areas contain public water supplies, releases within wellhead protection areas pose an increased risk of human exposure. For this reason, it is important to understand how likely it is for release-related chemicals in groundwater to make their way to the wellhead and result in an exceedance.

Potential lines of evidence to consider when deciding whether a release is likely to result in an exceedance of an unconditional groundwater remediation objective at a wellhead include time of travel to the wellhead, the existing extents and behavior of the plume, attenuation rates of release-related chemicals, and the magnitude of exceedance relative to the unconditional groundwater remediation objective. It may be necessary to use groundwater modeling to adequately predict whether an exceedance will occur, and whether a remedy is necessary to control risks from such an exceedance. If modeling cannot adequately predict future exceedances, long-term groundwater monitoring may be

³⁷ If a drinking water well is already present in such a location, water from that well should be evaluated for groundwater exposure risk.

required. IDEM's Office of Land Quality will consult with IDEM's Office of Water Quality regarding closure decisions involving releases in wellhead protection areas.

3.4.7 Deciding Whether a Remedy is Necessary for Vapor

This subsection concerns remedy decisions for vapors that arise from releases of volatile chemicals³⁸ to land and groundwater and then enter or have the potential to enter structures via vapor intrusion. Releases directly to the atmosphere may be regulated by IDEM's Office of Air Quality. Commercial use of volatile chemicals inside structures may be regulated by either the Indiana Occupational Safety and Health Administration or the U.S. Occupational Safety and Health Administration (OSHA), or both. If chemicals of concern are presently used at the facility, the chemicals found in indoor air are not associated with a past release, or the chemicals found in the facility are subject to air worker standards, that information should be supplied to better assess the need for a remedy.

In general, IDEM will require vapor remedies when vapor intrusion currently contributes to exceedances of unconditional remediation objectives in indoor air, or when the results of exterior soil gas or subslab soil gas sampling indicate that vapor intrusion could potentially cause an unacceptable risk in the future. Exterior soil gas and subslab soil gas levels are important because of their existing or potential contribution to vapor intrusion. Soil gas data is particularly important when evaluating the potential for vapor intrusion into structures that do not currently exist (e.g., at a potential building site.)

IDEM has determined that because vapor concentrations, particularly those inside buildings, are highly variable, conservative approaches are appropriate when evaluating risk from vapor intrusion. This is particularly true when making decisions based on small data sets, as is commonly the case in vapor intrusion investigations. For this reason, IDEM does not anticipate approving vapor remediation objectives based on a target cancer risk greater than 10^{-5} , unless the data supporting such proposals is temporally and spatially sufficient to provide assurance that representative concentrations are well understood and accurately reflect potential vapor exposure risk. Possibilities for accomplishing this include frequent sampling (perhaps with a portable analytical system) or with long-term passive sampling approaches.

Vapor remedy decisions must be supported by adequate vapor characterization including, at a minimum, the sampling described in Section 2.3.6. Also, because both vapors and their sources can move through the subsurface, vapor extents can change over time. Finally, new receptors may arise, as when a new home is built over an existing soil gas plume, or in the path of an oncoming soil gas plume. When this happens, vapors may affect receptors that were not previously affected or present. For these reasons, vapor remedy decisions must consider the likely future extents of subsurface vapor, both in soil gas and in preferential pathways, as well as potential future receptors.

3.4.7.1 Standard Vapor Remedy Decision Process

A standardized process for vapor remedy decisions appears below. It begins with indoor air sample results paired with either subslab or exterior soil gas results³⁹. Use results from the *first* round of paired samples to identify the response scenario corresponding to the appropriate row and column headings in Table 3-B. Note that this table does not address indoor air impacted by conduit vapors. If indoor air exceeds an unconditional remediation objective and conduit vapors are present, further investigation and/or a remedy is necessary. Table 3-C describes next steps for each of the scenarios contained in Table 3-B. *It is acceptable to use commercial remediation objectives instead of unconditional remediation*

³⁸ Defined for this purpose as a chemical having a vapor pressure greater than one millimeter of mercury at standard conditions.

³⁹ IDEM has determined that, whenever possible, paired samples should be collected during worst-case conditions.

objectives when evaluating existing or potential structures restricted to commercial use via land use controls.

Neither table is a substitute for critical thinking or best professional judgment. They are only general guides. Structure-specific decisions regarding mitigation options and the urgency and/or timing of action should be based on observed conditions. The conditions at any given structure may lead to different decisions than the simple suggestions provided in the tables. IDEM will evaluate alternate proposals on their merits.

Table 3-B: Matrix for comparison of paired indoor air and subslab/exterior soil gas results

	Indoor Air Concentration			
SGss/SGe Concentration	IA \leq URO	URO < IA \leq 2x URO	2x URO < IA \leq 10x URO	IA > 10x URO
SGss/SGe \leq URO	Scenario 1 <i>Remedy not necessary</i>	Scenario 4 <i>Indoor air source (4a) or conduit pathway likely (4b)</i>	Scenario 4 <i>Indoor air source (4a) or conduit pathway likely (4b)</i>	Scenario 4 <i>Indoor air source (4a) or conduit pathway likely (4b)</i>
URO < SGss/SGe \leq 2x URO	Scenario 2 <i>Remedy typically not necessary</i>	Scenario 5 <i>Implement remedy or show through additional sampling and lines of evidence that a remedy is not needed</i>	Scenario 6 <i>Implement remedy</i>	Scenario 7 <i>Promptly implement a remedy</i>
2x URO < SGss/SGe \leq 10x URO	Scenario 3 <i>Implement remedy or indefinite sampling</i>	Scenario 6 <i>Implement remedy</i>	Scenario 6 <i>Implement remedy</i>	Scenario 7 <i>Promptly implement a remedy</i>
SGss/SGe > 10x URO	Scenario 3 <i>Implement remedy or indefinite sampling</i>	Scenario 6 <i>Implement remedy</i>	Scenario 6 <i>Implement remedy</i>	Scenario 7 <i>Promptly implement a remedy</i>

IA = indoor air SGe = exterior soil gas SGss = subslab soil gas URO = unconditional remediation objective

Examples:

If concentrations of trichloroethene are 2.5 times its unconditional remediation objective in subslab soil gas and 4 times its unconditional remediation objective in indoor air, Scenario 6 applies.

If concentrations of benzene are less than its unconditional remediation objective in indoor air but 20 times its unconditional remediation objective in subslab soil gas, Scenario 3 applies.

Table 3-C: Vapor Remedy Decision Scenarios

Scenario 1	Resample under worst-case conditions. If both rounds of paired worst-case sampling results show that the SGss/SGe and indoor air concentrations are below unconditional remediation objectives, neither a vapor remedy nor additional sampling is necessary. If the second round yields a different scenario from the first, implement the most protective scenario or perform additional sampling and/or present lines of evidence that support a different course of action.	
Scenario 2	These VOC levels in SGss/SGe indicate the potential for vapor intrusion, and additional evaluation is warranted. If three paired worst-case sampling events (winter season, summer season, repeat of winter/summer season) show that SGss/SGe is less than two times unconditional remediation objectives, and indoor air concentrations do not exceed unconditional remediation objectives, vapor intrusion does not pose an unacceptable risk and neither a remedy nor additional sampling is necessary. If any of the sample rounds yield a different scenario, implement the most protective scenario and/or perform additional sampling and present lines of evidence that support a different course of action.	
Scenario 3	There is significant potential for future vapor intrusion. Implement a remedy or monitor SGss/SGe and indoor air concentrations until a remedy proves either necessary or unnecessary.	
Scenario 4	This scenario typically occurs when (a) there is an indoor source of the observed chemical(s) or (b) a preferential pathway (e.g., open conduit) bypasses the soil. To evaluate these scenarios, identify and, if possible, remove any indoor sources, then resample indoor air, SGss, and conduit vapor. Typically, two sampling results are the minimum needed to evaluate vapor intrusion, though contradictory results will warrant additional sampling. If sampling consistently shows:	
	(a) SGss or SGe < unconditional remediation objectives, indoor air < unconditional remediation objectives, and conduit vapor < unconditional remediation objectives, neither a remedy nor further sampling is necessary. If the indoor air source is known, lines of evidence may allow a single round of resampling.	(b) SGss or SGe < unconditional remediation objectives, indoor air > unconditional remediation objectives, and conduit vapor > unconditional remediation objectives, corrective action and/or additional sampling is warranted.
Scenario 5	In this scenario, vapor intrusion is occurring. Responsible parties should either implement a remedy or demonstrate through additional sampling and lines of evidence that a remedy is not necessary.	
Scenario 6	In this scenario, there is strong evidence that vapor intrusion is occurring. Responsible parties should implement a remedy that achieves and maintains acceptable indoor air levels.	
Scenario 7	In this scenario, there is very strong evidence that vapor intrusion is occurring. Because observed concentrations in indoor air exceed action levels, responsible parties should promptly implement a remedy that achieves and maintains acceptable indoor air levels.	

3.4.8 Deciding Whether a Remedy is Necessary for Other Media

Because releases do not always remain confined to soil, groundwater, and vapor, it is sometimes necessary to decide whether a remedy is required to control risk arising from release-related chemicals in other media, such as surface water or sediment. Closure decisions for these media may need to involve IDEM's Office of Water Quality or other State of Indiana or Federal agencies.

3.4.8.1 Surface Water Remedy Determinations

Per [327 IAC 2-11-5\(3\)](#), surface water quality standards shall be met in the surface waters of the state at the groundwater – surface water interface. Pore water samples are technically most appropriate for this purpose. Indiana's surface water quality standards appear in [327 IAC 2-1-6](#). U.S. EPA Region 4 levels (U.S. EPA, 2018) are acceptable for those chemicals for which IDEM does not publish surface water quality standards. Because pore water samples are not as replicable as monitoring well samples, calculation of UCLs from pore water data series is not advised. Instead, IDEM expects that most remedy decisions for surface water will be made via direct comparison of sample results against surface water quality standards, where an exceedance means a remedy is necessary, unless appropriate lines of evidence show otherwise.

3.4.8.2 Sediment Remedy Determinations

Sediment intended for eventual placement on land should be evaluated against soil criteria, with remedy decisions employing the same approach as that applicable to soil remedy decisions. Where ecological concerns apply, IDEM recommends that remedy decisions for sediment left in place should compare U.S. EPA Region 4 (or equivalent) ecological screening levels for chemicals in sediment against representative concentrations of release-related chemicals in sediment. Calculate the latter using procedures analogous to those for soil. If representative concentrations exceed appropriate sediment screening levels, a remedy is necessary unless appropriate lines of evidence show otherwise. Additional ecological risk evaluation guidance appears in Appendix D.

3.4.9 Risk Characterization

Also known as forward risk assessment, risk characterization combines exposure assessment with toxicity assessment to provide an estimate of risk, and usually an evaluation of the uncertainty and bias associated with that risk estimate. For example, risk characterizations should, to the extent possible, provide central tendency risk estimates in conjunction with upper bound risk estimates and a clear statement of the uncertainty associated with those estimates. Especially when coupled with realistic exposure assumptions, risk characterization provides a more meaningful evaluation of risks associated with a release than does simple application of published levels. The result should better inform decision making. However, risk characterization is typically far more resource intensive than using screening levels or even site-specific levels. Responsible parties will need to weigh the costs and potential benefits of each approach for themselves. A full description of the risk characterization process is beyond the scope of this document. U.S. EPA (1992c, 2000c) provides detailed guidance.

3.4.10 How IDEM Will Evaluate Remedy Necessity Determinations

Soil Exposure Remedy Decisions

- Is an interim remedy necessary for any decision unit?
- Has a remedy decision been proposed for each decision unit?
- Are spatially grouped exceedances evaluated appropriately?
- If a representative concentration in a decision unit exceeds its unconditional remediation objective and a remedy is not proposed, is that proposal supported by adequate lines of evidence?

Leaching Potential Remedy Decisions

- Has a remedy decision been proposed for each decision unit?
- Are spatially grouped exceedances evaluated appropriately?
- If a representative concentration in a decision unit exceeds its unconditional remediation objective and a remedy is not proposed, is that proposal supported by adequate lines of evidence?

Groundwater Remedy Decisions

- Is an interim remedy necessary?
- Has a remedy decision been proposed for each decision unit?
- Are spatially grouped exceedances evaluated appropriately?
- Do representative concentrations exhibit trends or seasonal exceedances?
- If a representative concentration in a decision unit exceeds its unconditional remediation objective and a remedy is not proposed, is that proposal supported by adequate lines of evidence?

Vapor Remedy Decisions

- Is an interim remedy necessary?
- Has a remedy decision been proposed for each decision unit?
- If a representative concentration in a decision unit exceeds its unconditional remediation objective and a remedy is not proposed, is that proposal supported by adequate lines of evidence?

4. Remedies

In the context of this guidance, a **remedy** is a means of reducing risk arising from a release-related chemical. A remedy either reduces the concentrations of one or more release-related chemicals, reduces exposure to those chemicals, or both. Remedies need not stand alone, and in many cases adequately controlling risk will require a combination of remedies. For example, adequately controlling soil exposure risk may require a remedy different than a remedy that adequately controls vapor intrusion risk. A remedy may be implemented for a single decision unit or many decision units.

Remedies that achieve unconditional closure at a decision unit allow that decision unit to be used for any purpose, and do not require ongoing obligations. Achieving an unconditional closure requires showing that any remaining concentrations of release-related chemicals or risks associated with those chemicals are no higher than unconditional remediation objectives, or that convincing lines of evidence demonstrate that a remedy is not necessary.

Remedies that do not achieve unconditional closure at a decision unit require ongoing obligations. Examples of such obligations include one or more activities that must occur (e.g., installation and maintenance of a barrier and/or active remediation system), must not occur (e.g., a land use restriction that prohibits specified activities), or combinations thereof. Those obligations must remain in effect for as long as release-related chemicals are likely to remain in the decision unit at levels that would result in unacceptable risk in the absence of the remedy.

Interim Remedies

The formal remedy selection process is typically undertaken after the release is fully characterized and an evaluation of risks to human health and the environment indicates that a remedy is required. However, it may sometimes be necessary or advisable to implement a remedy before the nature and extent of a release is fully characterized. For example, unacceptable risks (e.g., persons drinking water that exceeds maximum contaminant levels (MCLs) or breathing indoor air that exceeds indoor air action levels) should be prioritized and controlled to protect human health. Other activities, such as removal of source material, may reduce potential risk, overall project cost, and time to closure.

If they do not create an unacceptable hazard or worsen risks arising from a release, IDEM does not object to, and may encourage, implementation of one or more interim remedies at any stage of a project. Note, however, that per [IC 13-25-5-8.5\(c\)\(1\)](#), a *complete* evaluation of risk (and therefore the adequacy of whatever remedy is ultimately proposed) requires adequate characterization of the nature and extent of the release. It is not acceptable to implement a remedy in lieu of adequate characterization.

Section 4 Structure

Section 4.1 provides guidance on the selection of remedies likely to be effective in controlling release-related risk at a decision unit. Section 4.2 provides guidance on implementing remedies and demonstrating that they effectively control risk at a decision unit.

4.1 Task Eight: Select an Adequate Remedy

Task eight corresponds to submission of a proposed remediation work plan or corrective action plan. An **adequate remedy** is one that will reduce risk from release-related chemicals to a level that is acceptable for the intended use of a decision unit. Risks can be controlled by reducing concentrations of release-related chemicals, by reducing receptor exposure to those chemicals, or through some combination of those two general approaches. Rather than prescribing specific remedies, IDEM will evaluate the adequacy of a remedy for both current and future exposures. In some cases, long-term stewardship (Section 4.1.7) will be necessary to ensure remedy adequacy.

4.1.1 Basis for Requirement

[IC 13-25-5-8.5\(c\)](#) describes circumstances under which additional action *is not* necessary to protect human health or the environment. In all other circumstances, additional action *is*, in the absence of convincing lines of evidence to the contrary, necessary to protect human health or the environment. An adequate remedy must be likely to adequately control risk for the likely lifetime of release-related chemicals. An adequate remedy must also meet any additional applicable state or federal requirements.

4.1.2 Remedy Selection: General Considerations

IDEM has determined that many different technologies and tactics are potentially useful for reducing risks arising from release-related chemicals and, except as noted below, the agency does not generally prescribe specific approaches. Instead, responsible parties are generally free to consider the advantages and disadvantages of various remedy options for themselves. Factors to consider include:

- *Effectiveness.* Will the remedy adequately control risk, and do so for as long as release-related chemicals are present at levels exceeding unconditional remediation objectives?
- *Timeliness.* Will the remedy control risk quickly enough? A remedy that takes many years to adequately control risk is little better than no remedy.
- *Cost, including cost over time.* Long-term costs associated with the ongoing obligations of a conditional closure may ultimately prove more expensive than achieving an unconditional closure. IDEM will take a special interest in cost when the state acts either in its capacity as Administrator of the Excess Liability Trust Fund or as a party undertaking a response with state funding sources.
- *Acceptability to affected parties.* For example, a remedy that requires placement of an environmental restrictive covenant on a deed must be acceptable to the owner of the relevant property.
- *Potential, if any, to make the original situation worse.* Examples of this include remedies that increase the area affected by the release, or remedies that transform the originally released chemical into a more toxic or otherwise dangerous form or byproduct.
- *Planned use of decision units.* The level of confidence in future planned use is important when assessing potential risk posed by the release.
- *Experience with the proposed remedy.* All else equal, obtaining IDEM approval of a remedy with an established record of success will likely require less documentation of suitability than would a novel remedy, and may require less time for agency review.

4.1.3 Remedy Selection: Statutory Requirements

[IC 13-25-5-7\(b\)](#) and [IC 13-25-5-7\(c\)](#) describe requirements applicable to either proposed or completed remediation work plans. Section 4.2.1 describes requirements for a completed work plan. Per [IC 13-25-5-7\(b\)](#),

A proposed voluntary remediation work plan must include the following:

(1) Detailed documentation of the investigation conducted by the applicant in preparing the proposed voluntary remediation work plan and a description of the work to be performed by the applicant to determine the nature and extent of the actual or threatened release.

(2) A proposed statement of work to accomplish the remediation in accordance with guidelines established by the department.

(3) Plans concerning the following:

(A) Quality assurance for the implementation of the proposed remediation project.

(B) Descriptions of sampling and analysis.

(C) Health and safety considerations.

(D) Community relations and community comment in planning, cleanup objectives, and implementation processes.

(E) Data management and record keeping.

(F) A proposed schedule concerning the implementation of all tasks set forth in the proposed statement of work.

Detailed documentation of investigative work

IDEM remediation programs may, at their discretion, allow incorporation of previously reported investigative work by reference. However, in instances where remediation work plans must be made available for public review, IDEM may require that those remediation work plans be comprehensive, stand-alone documents.

Statement of work

This is a description of the tasks necessary to implement the remediation work plan. Useful components include a map showing the extent(s) of release-related chemicals superimposed on the extent(s) of the proposed remedies, evidence that plan implementation will adequately control risks, and cost estimates comparing the proposed remedy with other alternatives, particularly when the project is eligible for reimbursement by the Excess Liability Trust Fund.

Quality assurance

This refers to a description of the measures planned or taken to ensure that data necessary for remedy design and implementation meet data quality objectives (DQOs). Section 2.2 contains additional discussion on DQOs.

Sampling and analysis

This is a description of the methods used to collect, preserve (when necessary), handle, and analyze samples of environmental media.

Health and safety

This is a description of measures planned or taken to ensure both the health and safety of workers implementing remedies and that of persons who may be affected by remedy implementation. Potential

topics will vary according to the proposed remedy type, and may include required safety training for project personnel, access controls, monitoring plans, contingency plans for emergencies, etc.

Community relations and comment

This is a description of measures planned or taken to meet community relations requirements. See IDEM (2021e) for additional guidance on this topic.

Data management and record keeping

This is a description of measures taken or planned to obtain, use, present, and retain data obtained during implementation of the remediation work plan.

Proposed schedule

This is a timetable that describes when important activities related to implementation of the remediation work plan will occur and demonstrates that the remedy will control risks in a timely manner.

In some cases, either due to changing circumstances or direction received from IDEM, proposed remediation work plans will need to be modified and resubmitted for IDEM review. Legal requirements, technical considerations, and lines of evidence may vary according to the type of remedy. As detailed below, active remedies, engineered exposure controls and institutional controls each have different considerations; additional discussion of proposed remediation work plan components follows for each of the three remedy categories.

4.1.4 Remedy Selection: Active Remedies

In the context of this guidance, IDEM defines an **active remedy** as a measure that significantly reduces release-related chemical concentrations in a decision unit. Active remedies have many potential benefits. These include possible **unconditional closure**, possible shortened monitoring and/or maintenance periods, a wider variety of future uses and possible reduced future liability. There are many types of active remedies. Examples include:

- Removal and disposal
- Bioremediation
- Groundwater pump and treat systems
- Soil vapor or multiphase extraction systems
- Certain chemical treatments
- Electrical resistance heating

Proposed remediation work plan components applicable to active remedies might include:

- Pilot test results from the project or a similar project, along with a detailed explanation of why conditions are similar at each.
- In some cases, additional characterization (for example correlating release-related chemical concentrations and permeability or a more detailed utility delineation) may provide evidence that an active remedy proposal is likely to work.
- A monitoring proposal to ensure remedies (e.g., injections or fracking) are controlled, don't mobilize release-related chemicals, or result in plume expansion.
- Pressure monitoring to show an inward gradient and an air sparge interlock with a soil vapor extraction system to ensure that sparging doesn't mobilize vapors.
- Contingency plans for certain reasonably likely scenarios. For example, a design for an extraction system or treatment wall in case the remedy mobilizes release-related chemicals.

Proposed schedules for active remedies are complicated by the many unknowns associated with implementation. For this reason, it is often necessary to propose performance monitoring criteria that will indicate whether the remedy was implemented as planned and is progressing. Long-term progress is typically shown through periodic monitoring of release-related chemical concentrations and system evaluation (if applicable). Monitoring and evaluation time frames will depend on the relative speed of the technique. Examples of active remedy progress measures include:

- Measurement of oxygen, ozone, tracer gas, etc. to determine air sparge radius of influence
- Vacuum monitoring points to determine soil vapor extraction radius of influence
- Visual/chemical observations in monitoring points to assess injection radius of influence

Proposed remediation work plans for active remedies must state the long-term remedy goal(s). Examples of acceptable goals include endpoint release-related chemical concentrations, percent reductions, system extraction rate declines, etc.

4.1.5 Remedy Selection: Engineered Exposure Controls

Some remedies, by reducing exposure, may reduce risk to acceptable levels, even without reducing concentrations of release-related chemicals. In the context of this guidance, IDEM defines one subset of such exposure control remedies – those that involve construction or use of some physical structure or apparatus to control exposure – as **engineered exposure controls**. Engineered exposure controls typically work by controlling the movement of chemicals or interrupting exposure pathways. As with other remedies, use of an engineered exposure control does not relieve a responsible party from their statutory obligation to adequately characterize a release. Examples of engineered exposure controls include:

- Engineered caps (e.g., to control soil exposure or leaching potential concerns)
- Vegetative covers
- Liners
- Slurry walls
- Immobilization or stabilization of release-related chemicals in soil (e.g., to control soil exposure or leaching potential concerns)
- Drinking water filter systems
- Vapor mitigation systems

IDEM approval of engineered exposure controls requires evidence that exposures will be adequately controlled both now and in the future. The type of evidence will depend on the type of control. Examples include:

- Indoor air testing for a vapor intrusion subslab depressurization system (present) accompanied by an operation and maintenance plan with ongoing indoor air testing (future)
- Potentiometric data indicating capture for a slurry wall (present) and an operation and maintenance plan that includes ongoing gradient monitoring (future)

IDEM (2021d) describes the data that may be necessary to document the performance of a given exposure control, including vapor mitigation systems, covers, fences, and slurry walls. IDEM may revise or issue additional guidance on other engineered exposure controls in the future.

Proposed remediation work plans that rely on engineered exposure controls must include operation and maintenance plans to ensure long-term reliability of engineered exposure controls and their ability to adequately control exposure in the future. A remedy that relies on an engineered exposure control must also include an environmental restrictive covenant that requires operation and maintenance of that control. In some cases, long-term monitoring and entry into a long-term stewardship agreement that includes financial assurance may be required.

Sometimes it is appropriate to submit operation and maintenance plans following implementation. For example, vapor mitigation systems are sometime installed as part of new construction when soil gas data did not clearly predict whether a system was necessary. If post-construction sampling shows that vapor is not a concern, then an operation and maintenance plan is not necessary. Otherwise, confirmatory sampling and an operation and maintenance plan is necessary.

4.1.6 Remedy Selection: Institutional Controls

Effective institutional controls eliminate or reduce exposure via certain exposure pathways by forbidding or restricting certain land uses on a property, or by compelling other activities (e.g., operation and maintenance of an engineered exposure control). There are many kinds of institutional controls, including environmental restrictive covenants, environmental restrictive ordinances, and deed notices. Specific guidance on environmental restrictive covenants and deed notices appears in Appendix E, while Appendix F provides guidance on environmental restrictive ordinances.

Sometimes, a release may necessitate a remedy on one or more properties other than the source property. If the approved remedy on such property is an ERC, it is the responsibility of the entity proposing the remedy to obtain the executed document and see that it is recorded. Exposure pathways may be eliminated for certain decision units owned by local governments or state agencies, such as rights-of-way or state-owned roads, by providing adequate notice to those local governments or state agencies. There are occasions when an ERC or ERO is necessary but for a myriad of reasons is not obtainable. IDEM acknowledges that these situations occur and that a solution is often complex. Releases that require notice of impacts to properties other than the source property, including notice to subsequent owners, will be addressed on a project-specific basis. If that is not possible, an alternative remedy may be necessary.

4.1.7 Long Term Stewardship (LTS)

U.S. EPA (2005c, page 6) states that “Long-term stewardship applies to sites where long-term management of contaminated environmental media is necessary to protect human health and the environment. Long-term stewardship generally includes the establishment and maintenance of physical and legal controls, implementation entities, authorities, accountability mechanisms, information and data management systems, and resources that are necessary to ensure that these sites remain protective of human health and the environment.” LTS can:

- Allow responsible parties/property owners to better manage on-going and future risks and liabilities
- Maintain the viability/protectiveness of engineered controls with finite lifespans such as vapor mitigation systems, slurry walls, soil caps, fencing, and other containment systems
- Calculate & “lock-in” cost of current and future liabilities
- Allow long-term oversight of remedy and liability protection after property sale and loss of direct property control
- Support the selection and use of institutional and engineering controls for a risk-based closure

At this time, IDEM has not fully developed an LTS plan, but will consider LTS on a case-by-case basis. While developing an LTS plan, consider the following components:

- Release setting details
- Controls – institutional & engineering
- Monitoring plan
- Operation and maintenance plan (engineering controls)
- Recordkeeping/notices
- Reporting
- Appendices/data collection forms
- Financial assurance

4.1.8 Financial Assurance

Some closure types require financial assurance, either because statute, federal rules, or other regulations require it, or because IDEM determines that financial assurance is required to protect taxpayers. Appendix G provides additional guidance on financial assurance.

4.1.9 How IDEM Will Evaluate Remedy Selection

IDEM will evaluate the information described above to determine if a remedy is likely to reduce exposure to acceptable levels within a reasonable timeframe and without unacceptably increasing other risks.

Criteria that IDEM will use to evaluate proposed remedies include the following:

Active Remedy Proposals

- Is the proposed remedy likely to be successful? The level of detail required to demonstrate the feasibility and likely success of the system will vary according to the project, but will likely increase if IDEM is paying for the remedy or acting as Administrator of the Excess Liability Trust Fund. See Section 4.1.4 for additional detail.
- Does the proposal include metrics for remediation progress and success? Post-implementation monitoring has two purposes. First, it shows whether the system was installed as proposed and is reducing release-related chemical concentrations as expected. Second, it should ultimately show whether the system has achieved proposed remediation end points.
- Does the proposal address any likely adverse effects or other issues described in Section 4.1.2?
- Are proposed endpoints and confirmatory metrics in various media consistent with acceptable risk levels, given the proposed use of relevant decision units?

Engineered Exposure Control Proposals

- Is the proposed control reasonably likely to adequately control exposure for as long as release-related chemicals are present above applicable remediation objectives?
- Does the proposal include adequate metrics for confirming that the control adequately controls exposure?
- Do proposed operation and maintenance plans for vapor mitigation systems conform with criteria described in Section 4.2.3.1?

Institutional Controls

- See Appendices E, F, and G as appropriate for guidance on how IDEM will evaluate proposed ERCs, proposed EROs, and financial assurance proposals.

4.2 Task Nine: Remedy Implementation and Confirmation

Because remedy implementation often involves multiple steps with varying levels of uncertainty, IDEM acknowledges that remedy proposals may require modification during or after implementation. If the implemented remedy differs significantly from the proposed remedy, IDEM will require documentation of those differences.

4.2.1 Basis for Requirement

Remedy implementation and confirmation is necessary to demonstrate compliance with [IC 13-25-5-8.5\(c\)](#). IDEM's remediation programs will typically require documentation of compliance with remedy confirmation requirements described in Sections 4.1.2, 4.1.3, 4.2.1, and 4.2.2 to show that the remedy as implemented is effective. Per [IC 13-25-5-7\(c\)](#), a voluntary remediation workplan for a completed remediation project must include the following:

- (1) Detailed documentation of the investigation conducted by the applicant in preparing the proposed voluntary remediation work plan and a description of the work performed by the applicant to determine the nature and extent of the actual or threatened release.
- (2) A statement of work performed to accomplish the remediation in accordance with rules or guidelines established by the department.
- (3) Plans concerning the following:
 - (A) Quality assurance for the implementation of and, if appropriate, plans for future oversight of the remediation project.
 - (B) Descriptions of sampling and analysis conducted before and after the remediation is performed.
 - (C) Health and safety considerations.
 - (D) Community comment.
 - (E) Data management and record keeping.
 - (F) Criteria used to determine remediation levels and remediation methodology.
- (4) Other information the department determines is necessary to evaluate the work plan and determine if the remediation objectives have been achieved.

4.2.2 Implementation and Confirmation of Active Remediation

Implementation of active remediation may involve any of many approaches to reduce concentrations of release-related chemicals. Discussion of how to implement those approaches is beyond the scope of this document.

Demonstrating active remediation effectiveness generally requires collection and analysis of samples from relevant media, and submission of those results to IDEM. If groundwater is or was impacted, this will usually include submission of at least four quarters of post-remediation groundwater monitoring data from appropriately located monitoring wells. Most demonstrations will use sample results to determine representative concentrations in decision units and compare those concentrations to appropriate remediation objectives. Confirmation that concentrations of release-related chemicals in a decision unit have been successfully reduced to levels below unconditional remediation objectives will typically result in unconditional closure. Per [IC 13-25-5-8.5\(c\)](#), exceedances of unconditional remediation objectives may require a remedy.

4.2.3 Implementation and Confirmation of Engineered Exposure Controls

There are many types of engineered exposure controls. IDEM (2021d) describes implementation of several types of engineered exposure controls, including vapor mitigation systems, covers, fences, and slurry walls. Because subslab depressurization systems (SSDS) to control vapor intrusion risk are the most common engineered exposure control proposed to IDEM, Section 4.2.3.1 provides additional guidance on implementation and confirmation of subslab depressurization systems. IDEM may issue additional guidance on other engineered exposure controls in the future.

Demonstrating engineered exposure control effectiveness requires showing that the control adequately controls relevant exposure pathways. It also generally requires submission of documentation that shows that those controls either conform to their proposed design or describes and justifies any significant changes. Operation, maintenance, and monitoring (OMM) plans tied to an appropriate institutional control or long-term stewardship agreement must be submitted to provide reasonable assurance of adequate exposure pathway control in the future.

Engineering controls should usually be supported by institutional controls that ensure those engineering controls stay in place and are maintained. For instance, an environmental restrictive covenant could be used to obligate continued OMM of any engineered exposure control used at a property. Written OMM plans that ensure long-term reliability of engineered exposure controls must be developed and submitted to IDEM for approval.

4.2.3.1 Implementation and Confirmation of an SSDS

SSDS are the most common vapor exposure control. AARST (2020, 2020b, 2020c) and ITRC (2021) contain appropriate design and performance metrics. Post implementation confirmatory testing must demonstrate that an SSDS is successfully mitigating the vapor intrusion pathway and is likely to continue doing so in the future. The confirmatory testing should consist of both indoor air sampling and documentation of system performance metrics. It takes time for the subslab and/or crawl space area to reach steady-state conditions after the installation of a vapor mitigation system. For this reason, an equilibration period (30 days is standard) is necessary before confirmatory indoor air sampling and performance metrics are collected.

Indoor air sampling is a necessary line of evidence to confirm the mitigation system is performing adequately. Verification indoor air sampling is only necessary for previously detected chemicals and their breakdown products. Indoor air samples should be collected in locations biased toward worst-case conditions identified during previous sampling events and/or based on professional judgment. Following installation of a vapor mitigation system, IDEM recommends the following:

- One round of indoor air sampling 30 days after system installation, with a second round of indoor air confirmatory sampling during worst-case conditions if the first round did not occur under worst-case conditions
- Documentation of baseline system performance measurements (e.g., manometer, gauge, or other appropriate measurements)
- Pressure field extension testing to demonstrate that a negative pressure differential exists between the subslab and indoor air

4.2.3.2 SSDS Operation, Maintenance, and Monitoring (OMM)

Routine long-term OMM of the vapor mitigation system will be necessary for as long as the vapor intrusion pathway requires interruption. For new construction or pre-emptive systems without conclusive data about the risk of vapor intrusion, OMM will be necessary unless data is presented to show the

system is not needed to interrupt the VI pathway. The system shutdown procedure described below Table 4-B is appropriate for showing that a system is not needed.

A project specific OMM plan should be developed that specifies the requirements for, and frequency of, indoor air sampling and vapor mitigation system inspection based on building characteristics and the risk level specific to each building. Table 4-A (below) provides general guidance on appropriate inspection and sampling intervals. Conditions at any given building may lead to different decisions than the approaches described below. Generally, an OMM plan should include:

- Routine visual inspections of buildings to ensure that there are no significant changes such as remodeled areas or additions to the buildings.
- Routine visual inspections of vapor mitigation systems, especially pressure gauges or manometers, to ensure that the system is functioning appropriately⁴⁰.
- Periodic monitoring of indoor air on the lowest routinely occupied floor to ensure that indoor air concentrations are below remediation objectives and that vapor intrusion does not present a health risk. Documentation of a subslab vacuum pressure differential in conjunction with visual inspection of the system may be used under certain conditions during the OMM phase of the project to confirm steady-state operational conditions and provide a line of evidence that the mitigation system continues to control vapor intrusion in lieu of continued indoor air testing. In general, this scenario would apply to buildings with minimal and consistent subslab exceedances and multiple rounds of indoor air testing to confirm operation. It is unlikely that IDEM will approve elimination of indoor air testing, but less frequent testing may be appropriate.

Table 4-A: Inspection and Sampling Intervals

	Premitigation Indoor Air Concentration			
SGss or SGe concentration	Indoor air < IDEM published level	Published level < indoor air < 2x IDEM published level	2x published level < indoor air < 10x IDEM published level	Indoor air > 10x IDEM published level
SGss or SGe < IDEM published level	None anticipated	None anticipated	None anticipated	None anticipated
Published level < SGss or SGe < 2x IDEM published level	None anticipated	Schedule 1	Schedule 2	Schedule 2
2x published level < SGss or SGe < 10x IDEM published level	Schedule 1 OR conduct on-going sampling	Schedule 1	Schedule 2	Schedule 2
SGss or SGe > 10x IDEM published level	Schedule 2	Schedule 2	Schedule 2	Schedule 2

⁴⁰ Telemetry monitoring (with fault notification) may replace, or reduce the frequency of, visual inspections.

Table 4-B: Mitigation System Monitoring Schedule

Schedule 1	Schedule 2
Perform activities specified in Section 4.2.3.2, generally on an annual basis. Annual sampling of indoor air during winter worst-case conditions during the first, second, and fifth year, and every fifth year thereafter.	Perform activities specified in Section 4.2.3.2, generally on an annual basis. Annual sampling of indoor air during winter worst-case conditions during the first, second, and fourth year, and every other year thereafter.

If release-related chemical concentrations are reduced to levels that no longer require vapor mitigation, it is acceptable to terminate operation of vapor intrusion mitigation systems. System termination decisions should typically be based on the results of both indoor air and SGss sampling, as paired sampling provides the most direct measure of system necessity. Prior to sampling for system termination, shut down the mitigation system for a period of at least 30 days to allow re-development of pre-mitigation subsurface conditions. Where possible, collect samples from the same locations initially used to evaluate vapor intrusion. Collect a round of paired samples during worst-case conditions and compare the results to Table 3-B. Use the procedures in Table 3-B (typically one to two more rounds of sampling) to determine whether it is appropriate to terminate system operation or pursue some other course of action. However, if indoor air samples cannot be obtained and preferential pathways have been eliminated, stand-alone SGss sample results may be sufficient for this demonstration. Because vapor mitigation systems directly prevent exposure to release-related chemicals, IDEM recommends submittal of sampling results and obtaining agency concurrence that mitigation systems are no longer necessary to adequately manage risk before system shutdown. If system operation is required by an ERC, that ERC must be modified prior to system shutdown.

4.2.4 Implementation and Confirmation of Institutional Controls

See Appendices E and F for detailed guidance on this topic.

4.2.5 How IDEM Will Evaluate Remedy Implementation and Confirmation

Active remedies

- Does data show that representative concentrations or risk levels in each decision unit meet remediation objectives specified in the remediation work plan?
- If representative concentrations remain above unconditional remediation objectives, have additional remedies been implemented, and are they likely to adequately control risk?
- Are representative concentrations increasing or likely to increase in the future?

Engineered exposure controls

- Was the control implemented according to the approved plan? If not, were significant deviations from that plan explained and justified where necessary to show adequate control of risk?
- If demonstrating the effectiveness of the engineered exposure control requires sampling data (e.g., for a vapor mitigation system), was data submitted that shows adequate control of risk?
- Will the proposed OMM plan ensure long-term control of risk, and is financial assurance available, if necessary, to ensure long-term effectiveness?
- Appropriate metrics specified?
- Control accompanied by appropriate institutional control that ensures continued OMM?
- Responsible party designated for OMM implementation?

Institutional controls

- See Appendices E and F.

Appendix A: Derivation of IDEM's Published Levels

[IC 13-25-5-8.5\(d\)\(1\)](#) provides that responsible parties may use “levels of hazardous substances and petroleum calculated by the department using standard equations and default values for particular hazardous substances or petroleum” as remediation objectives. The Indiana Department of Environmental Management (IDEM) calculates one or more of such levels for more than 700 chemicals and refers to those levels as published levels. This appendix describes the derivation of IDEM's published levels, which are published in a separate document on a schedule and in a format described below. See Section 3.3 for guidance on applying IDEM's published levels as remediation objectives, and Section 2.3 for guidance on using IDEM's published levels during extents delineation.

A.1 General Approach

IDEM relies on the values found in the Regional Screening Level (RSL) tables (U.S. EPA, 2021e and subsequent updates) and guidance from the Regional Screening Level User's Guide (U.S. EPA, 2021f and subsequent updates) when deriving its published levels. However, for reasons explained in this appendix, IDEM's published levels are not necessarily the same as those that appear in the RSL tables. Among other things, IDEM adjusts the target cancer risk for carcinogens from 10^{-6} to 10^{-5} when deriving its published levels from the RSLs. Also, whereas U.S. EPA publishes RSL tables for noncancer hazard quotients of both 0.1 and 1, IDEM uses a target hazard quotient for noncarcinogenic risk of 1. IDEM's published levels tables do not include levels for total petroleum hydrocarbons, midrange aliphatic hydrocarbon streams, or coke oven emissions.

Although IDEM's published levels can be used as remediation objectives, they do not necessarily have to be met to achieve closure. IDEM's published levels are simply one type of remediation objective. However, when adequate characterization of a release shows that all representative concentrations in a decision unit are below **unconditional remediation objectives** (e.g., IDEM's residential published levels, site-specific residential levels, or naturally occurring background levels), a remedy is not required per [IC 13-25-5-8.5\(c\)](#).

A.2 Revision Schedule

IDEM plans to revise its published levels yearly, using the procedures described herein, and post each year's set of tables on its [Screening and Closure Level Tables webpage](#). IDEM will base the revision for each year on the U.S. EPA RSL tables that were in effect on the last day of the *preceding* year. All versions of IDEM's published levels will be available through links on the IDEM website. IDEM may also, at its discretion, publish one or more abbreviated tables that contain a subset of the chemicals that appear in the complete table, with an emphasis on those chemicals most likely to drive risk and remedy decisions.

A.3 Table Structure

IDEM plans to publish two tables each year. Table 1 contains most of IDEM's published levels, while Table 2 contains only levels for soil under three different recreational exposure scenarios. Table 1 has 14 columns, and Table 2 has five columns. The first column of each table contains the names of individual chemicals or chemical mixtures. Most chemical names are alphabetized, with numerical prefixes moved to the end of the chemical names. Polychlorinated biphenyls (PCBs) and dioxins are the exceptions; they appear under PCB: or Dioxin: respectively, followed by the chemical name. IDEM follows U.S. EPA nomenclature with respect to chemical names, and the IDEM published levels table makes no special attempt to include or cross-reference any of the myriad synonyms for chemical names. Instead, Chemical Abstract Service Registry Numbers (CASRNs) accompany each chemical name and provide a unique identifier useful for reconciling chemical synonyms. CASRNs appear in the second column of each table.

Subsequent columns in each table contain media-specific chemical concentrations suitable for evaluating risk or potential risk under a specific exposure scenario. Table 1 has columns for three soil exposure scenarios, groundwater, two indoor air exposure scenarios, and six columns of levels for potential exposures arising from soil gas. Table 2 is specific to recreational exposures to soil, and contains columns for community park, playing field, and recreational trail exposure scenarios.

A.4 Derivation of IDEM's Published Levels

The following subsections describe the procedures that IDEM uses to derive its published levels. Except for three groundwater levels that default to U.S. EPA MCLs, IDEM publishes all of the levels described below using a single significant digit and scientific notation.

A.4.1 Soil Levels

IDEM's published levels for soil assume exposure via ingestion, dermal contact, and inhalation of volatiles and particulates. Both tables contain soil levels for three different exposure scenarios, all in milligrams per kilogram (mg/kg). Note that IDEM caps some of its published levels for soil at either the soil saturation limit or the maximum cap, as described below. Except for excavation worker levels, IDEM does not publish soil levels for volatile chemicals, defined for this purpose as chemicals listed as having a vapor pressure equal to or greater than one millimeter of mercury in the RSL Chemical-specific Parameters Supporting Table. This is because volatile chemicals in exposed soil have short half-lives relative to the exposure durations assumed by U.S. EPA's equations for residential and commercial soil.

The soil saturation limit (C_{sat}) is the concentration in soil at which a chemical exceeds the absorptive limits of the soil particles. Chemicals at concentrations above C_{sat} may be present as free phase product, and U.S. EPA (2021f) notes that the presence of free phase chemicals may violate assumptions underlying the RSL equations. IDEM intends exceedance of the soil saturation cap to prompt further evaluation of decision units that may contain free phase chemicals. IDEM uses C_{sat} values, when available from the RSL Summary Table, to cap its published levels for soil.

U.S. EPA (2021f) notes that chemical concentrations greater than ten percent (100,000 mg/kg) may violate some RSL equation assumptions related to soil adherence and wind-borne dispersion. For this reason, IDEM caps its published levels for soil at 100,000 mg/kg. Qualifiers next to IDEM's published levels for soil indicate the following: C = carcinogenic endpoint; L = level capped at 100,000 milligrams per kilogram (mg/kg); N = noncarcinogenic endpoint; S = level capped at soil saturation limit.

A.4.1.1 Residential Soil Levels

The third column of Table 1 contains levels for the residential soil exposure scenario. IDEM derives the levels from values appearing in the U.S. EPA RSL resident soil table as follows:

1. Multiply the carcinogenic screening level (if any) appearing in the RSL resident soil table by ten to produce a carcinogenic level at a target cancer risk of 10^{-5} . Multiply the resulting number by a factor of 1.4 to account for IDEM's exposure frequency assumption (250 days/year) versus the U.S. EPA default exposure frequency (350 days/year).
2. Select the lower of the following as the IDEM published level for residential soil:
 - The 10^{-5} carcinogenic level (if any) as derived in Step 1, above
 - The noncarcinogenic screening level (if any) appearing in the RSL resident soil table, multiplied by 1.4
 - The C_{sat} value (if any) appearing in the RSL resident soil table
 - 100,000 mg/kg

3. Delete any residential soil levels for chemicals with a vapor pressure listed as equal to or greater than one millimeter of mercury in the RSL Chemical-specific Parameters Supporting Table.

For the residential soil exposure scenario, IDEM adopted U.S. EPA's residential screening level for lead. U.S. EPA considers this level protective of young children in a residential setting (U.S. EPA, 1994b). If U.S. EPA changes their residential screening level for lead, IDEM will adopt the new U.S. EPA level.

A.4.1.2 Commercial Soil Levels

The fourth column of Table 1 contains levels for the commercial soil exposure scenario. IDEM derives these levels from values appearing in the U.S. EPA RSL Composite Worker Soil table as follows:

1. Multiply the carcinogenic screening level (if any) appearing in the RSL Composite Worker Soil table by ten to produce a carcinogenic level at a target cancer risk of 10^{-5} .
2. Select the lower of the following as the IDEM published level for commercial soil:
 - The 10^{-5} carcinogenic level (if any) as derived in Step 1, above
 - The noncarcinogenic screening level (if any) appearing in the RSL Composite Worker Soil table (Hazard Quotient = 1)
 - The Csat value (if any) appearing in the RSL Composite Worker Soil table
 - 100,000 mg/kg
3. Delete any commercial soil levels for chemicals with a vapor pressure listed as equal to or greater than one millimeter of mercury in the RSL Chemical-specific Parameters Supporting Table.

IDEM calculates lead screening levels for the commercial soil exposure scenario using U.S. EPA's Adult Lead Model (U.S. EPA, 2003).

A.4.1.3 Excavation Worker Soil Levels

The fifth column of Table 1 contains levels, expressed in mg/kg, for the excavation worker soil exposure scenario. IDEM derives excavation worker soil levels using the industrial soil screening levels published in U.S. EPA's RSLs, adjusted for somewhat different exposure assumptions than those used by U.S. EPA. Table A-1 compares the different exposure assumptions that IDEM uses to derive excavation soil levels from commercial soil levels.

Table A-1: Exposure Assumptions

	Commercial	Excavation
Averaging time (years)	25 (non-cancer) 70 (carcinogen)	1 (non-cancer) 70 (carcinogen)
Exposure frequency (days/year)	250	45
Exposure duration (years)	25	1
Ingestion rate (milligrams/day)	100	330

Application of these parameter assumptions and the equations in Section 4.2 of U.S. EPA (2021f) yields the following relationships between levels for the excavation worker and commercial exposure scenarios.

Equation A-1: Ingestion of Noncarcinogens for the Excavation Worker Scenario

$$IL_{Exc-Ing-NC} = \left(\frac{500}{297}\right) IRSL_{CI-Ing-NC}$$

Where $IL_{Exc-Ing-NC}$ is an intermediate excavation worker level (used in Equation A-7, below) for the noncarcinogenic ingestion exposure pathway, and $IRSL_{CI-Ing-NC}$ is IDEM's intermediate level for commercial noncarcinogenic ingestion, which is the same as U.S. EPA's noncancer ingestion screening level from their Composite Worker Soil Table.

Equation A-2: Dermal Contact with Noncarcinogens for the Excavation Worker Scenario

$$IL_{Exc-Der-NC} = \left(\frac{50}{9}\right) IRSL_{CI-Der-NC}$$

Where $IL_{Exc-Der-NC}$ is an intermediate excavation worker level (used in Equation A-7, below) for the noncarcinogenic dermal exposure pathway, and $IRSL_{CI-Der-NC}$ is IDEM's intermediate level for commercial noncarcinogenic dermal contact, which is the same as U.S. EPA's noncancer dermal screening level from their Composite Worker Soil Table.

Equation A-3: Inhalation of Noncarcinogens for the Excavation Worker Scenario

$$IL_{Exc-Inh-NC} = \left(\frac{50}{9}\right) IRSL_{CI-Inh-NC}$$

Where $IL_{Exc-Inh-NC}$ is an intermediate excavation worker level (used in Equation A-7, below) for the noncarcinogenic inhalation exposure pathway, and $IRSL_{CI-Inh-NC}$ is IDEM's intermediate level for commercial noncarcinogenic inhalation, which is the same as U.S. EPA's noncancer inhalation screening level from their Composite Worker Soil Table.

Equation A-4: Ingestion of Carcinogens for the Excavation Worker Scenario

$$IL_{Exc-Ing-Carc} = \left(\frac{12,500}{297} \right) IRS_{L_{CI-Ing-Carc}}$$

Where $IL_{Exc-Ing-Carc}$ is an intermediate excavation worker level (used in Equation A-8, below) for the carcinogenic ingestion exposure pathway, and $IRS_{L_{CI-Ing-Carc}}$ is IDEM's intermediate level for commercial carcinogenic ingestion, which is ten times U.S. EPA's carcinogenic ingestion screening level from their Composite Worker Soil Table.

Equation A-5: Dermal Contact with Carcinogens for the Excavation Worker Scenario

$$IL_{Exc-Der-Carc} = \left(\frac{1,250}{9} \right) IRS_{L_{CI-Der-Carc}}$$

Where $IL_{Exc-Der-Carc}$ is an intermediate excavation worker level (used in Equation A-8, below) for the carcinogenic dermal contact exposure pathway, and $IRS_{L_{CI-Der-Carc}}$ is IDEM's intermediate level for commercial carcinogenic dermal exposure, which is ten times U.S. EPA's carcinogenic dermal screening level from their Composite Worker Soil Table.

Equation A-6: Inhalation of Carcinogens for the Excavation Worker Scenario

$$IL_{Exc-Inh-Carc} = \left(\frac{1,250}{9} \right) IRS_{L_{CI-Inh-Carc}}$$

Where $IL_{Exc-Inh-Carc}$ is an intermediate excavation worker level (used in Equation A-8, below) for the carcinogenic inhalation exposure pathway, and $IRS_{L_{CI-Inh-Carc}}$ is IDEM's intermediate level for commercial carcinogenic inhalation exposure, which is ten times U.S. EPA's carcinogenic inhalation screening level from their Composite Worker Soil Table.

Equation A-7: Noncarcinogenic Level for the Excavation Worker Scenario

$$IL_{Exc-NC} = \frac{1}{\left(\frac{1}{IL_{Exc-Ing-NC}} \right) + \left(\frac{1}{IL_{Exc-Der-NC}} \right) + \left(\frac{1}{IL_{Exc-Inh-NC}} \right)}$$

Where the value of any quotient in parentheses is set to zero when its denominator is zero.

Equation A-8: Carcinogenic Level for the Excavation Worker Scenario

$$IL_{Exc-Carc} = \frac{1}{\left(\frac{1}{IL_{Exc-Ing-Carc}} \right) + \left(\frac{1}{IL_{Exc-Der-Carc}} \right) + \left(\frac{1}{IL_{Exc-Inh-Carc}} \right)}$$

Where the value of any quotient in parentheses is set to zero when its denominator is zero.

IDEM selects the lower of the noncarcinogenic level (Equation A-7), carcinogenic level (Equation A-8), Csat, and 100,000 mg/kg as the IDEM published level for the excavation worker scenario. IDEM calculates lead screening levels for the excavation worker scenario using U.S. EPA's Adult Lead Model (U.S. EPA, 2003).

Note that this approach uses the chronic toxicity parameter values employed in the derivation of IDEM's published levels for commercial soil. Where available, subchronic toxicity parameter values may be more appropriate when deriving levels for the excavation worker soil exposure scenario.

A.4.1.4 Recreational Soil Levels – Community Park

The third column of Table 2 contains levels for the recreational soil community park exposure scenario. IDEM calculates published levels for the recreational soil community park exposure scenario using the Recreator scenario module found in U.S. EPA's RSL Calculator, and the user-specified parameter values found in Table A-2 below. IDEM does not publish soil levels for chemicals listed as having a vapor pressure listed as equal to or greater than one millimeter of mercury in the RSL Chemical-specific Parameters Supporting Table.

Table A-2: Recommended Exposure Parameter Inputs for the Community Park Scenario

Age Segment (yr)	Adherence Factor ^a (AF) (mg/cm ²)	Body Weight ^b (BW) (kg)	Exposure Duration (ED) (yr)	Exposure Frequency ^c (EF) (day/yr)	Exposure Time ^d (ET) (hr/event)	Intake Rate ^e (IRS) (mg/day)	Skin Surface Area ^c (SA) (cm ² /day)
0 thru 2	0.2	15	2	75	2	100	2,600
2 thru 6	0.2	15	4	75	2	100	2,900
6-16	0.2 ^c	80	10	104	2	100	5,000
16-26	0.07	80	10	75	2	50	5,700

Hazard Quotient	1
Target Cancer Risk	10 ⁻⁵
Climatic Zone	Chicago
Fraction of vegetative cover	0.8

Parameter value sources:

^aU.S. EPA (2004, Exhibit 3-3)

^bU.S. EPA (2011, Table 8-1)

^cIDEM (Best professional judgment)

^dU.S. EPA (2011, Table 5-1)

^eU.S. EPA (2004, Exhibit C-1)

A.4.1.5 Recreational Soil Levels – Playing Field

The fourth column of Table 2 contains levels for the recreational soil playing field exposure scenario. IDEM calculates published levels for the recreational soil playing field exposure scenario using the Recreator scenario module found in U.S. EPA's RSL Calculator, and the user-specified parameter values found in Table A-3 below. IDEM does not publish soil levels for chemicals with a vapor pressure listed as equal to or greater than one millimeter of mercury in the RSL Chemical-specific Parameters Supporting Table. Note that this scenario assumes an exposure frequency of thirty days. At some high-use sports fields it may be necessary to evaluate whether this assumption is reasonable. If a higher frequency is appropriate, then adjust the exposure frequency values in the table below accordingly.

Table A-3: Recommended Exposure Parameter Inputs for the Playing Field Scenario

Age Segment (yr)	Adherence Factor ^{a,c} (AF) (mg/cm ²)	Body Weight ^b (BW) (kg)	Exposure Duration (ED) (yr)	Exposure Frequency ^c (EF) (day/yr)	Exposure Time ^d (ET) (hr/event)	Intake Rate ^c (IRS) (mg/day)	Skin Surface Area ^c (SA) (cm ² /day)
0 thru 2	0.12	15	2	30	2	100	2,600
2 thru 6	0.12	15	4	30	2	100	2,900
6-16	0.12	80	10	30	3	100	5,000
16-26	0.07	80	10	30	2	50	5,700

Hazard Quotient	1
Target Cancer Risk	10 ⁻⁵
Climatic Zone	Chicago
Fraction of vegetative cover	0.8

Parameter value sources:

^aU.S. EPA (2004, Exhibit 3-3)

^bU.S. EPA (2011, Table 8-1)

^cIDEM (Best professional judgment)

^dU.S. EPA (2011, Table 5-1)

^eU.S. EPA (2004, Exhibit C-1)

A.4.1.6 Recreational Soil Levels - Trail

The fifth column of Table 2 contains levels for the recreational soil trail exposure scenario. IDEM calculates published levels for the recreational soil trail exposure scenario using the recreator scenario module found in U.S. EPA's RSL Calculator, and the user-specified parameter values found in Table A-4 below. IDEM's ingestion rates for the trail scenario are much lower than those appearing in the U.S. EPA's Exposure Factors Handbook and reflect IDEM's intent that these values be used for capped trails, such as a paved multi-use path for walking, cycling, jogging, skating and other activities. IDEM does not publish soil levels for chemicals with a vapor pressure listed as equal to or greater than one millimeter of mercury in the RSL Chemical-specific Parameters Supporting Table.

Table A-4: Recommended Exposure Parameter Inputs for the Trail Scenario

Age Segment (yr)	Adherence Factor ^a (AF) (mg/cm ²)	Body Weight ^b (BW) (kg)	Exposure Duration (ED) (yr)	Exposure Frequency ^c (EF) (day/yr)	Exposure Time ^d (ET) (hr/event)	Intake Rate ^c (IRS) (mg/day)	Skin Surface Area ^{c,e} (SA) (cm ² /day)
0 thru 2	0.04	15	2	75	1	6	2,600
2 thru 6	0.04	15	4	75	1	6	2,900
6-16	0.04	80	10	104	1	6	5,000
16-26	0.04	80	10	75	1	3	5,700

Hazard Quotient	1
Target Cancer Risk	10 ⁻⁵
Climatic Zone	Chicago
Fraction of vegetative cover	0.99

Parameter value sources:

^aU.S. EPA (2004, Exhibit 3-3)

^bU.S. EPA (2011, Table 8-1)

^cIDEM (Best professional judgment)

^dWolter, *et. al.* (2001).

^eU.S. EPA (2004, Exhibit C-1)

A.4.2 Groundwater Levels

Column six of Table 1 contains levels for the residential groundwater exposure scenario, expressed in micrograms per liter (µg/l). Residential groundwater levels account for exposures through ingestion of water, dermal contact with water, and inhalation of volatile chemicals arising from groundwater, as reasonably likely to occur in a home. Consistent with U.S. EPA, IDEM does not publish levels for any of the many possible commercial groundwater exposure scenarios.

For chemicals that have an MCL established under the Safe Drinking Water Act, IDEM uses the MCL as its published level for residential groundwater. For chemicals without MCLs, IDEM derives published levels for residential groundwater from values that appear in the U.S. EPA RSL Resident Tapwater Table as follows:

1. Multiply the value (if any) appearing in the carcinogenic screening level column of the RSL Resident Tapwater Table by ten to produce a carcinogenic screening level at a target cancer risk of 10^{-5} .
2. Select the lower of the 10^{-5} carcinogenic screening level derived above (if any) and the value (if any) appearing in the noncarcinogenic screening level column of the RSL Resident Tapwater Table as the IDEM published level for residential groundwater.

Qualifiers next to IDEM's published levels for groundwater indicate the following: C = carcinogenic endpoint; M = level set to maximum contaminant level established under the Safe Drinking Water Act; N = noncarcinogenic endpoint.

A.4.3 Indoor Air Levels

IDEM derives and publishes levels for two different indoor air scenarios - residential indoor air and commercial indoor air, expressed in micrograms per cubic meter (µg/m³). IDEM's published levels for indoor air assume exposure via inhalation of volatile chemicals. IDEM does not publish indoor air levels for nonvolatile chemicals, defined for this purpose as having a vapor pressure listed as less than one millimeter of mercury in the RSL Chemical-specific Parameters Supporting Table. Qualifiers next to IDEM's published levels for indoor air indicate the following: C = carcinogenic endpoint; N = noncarcinogenic endpoint.

A.4.3.1 Residential Indoor Air Levels

Column seven of Table 1 contains levels for the residential indoor air exposure scenario. IDEM derives these levels from values appearing in the U.S. EPA RSL Resident Air Table as follows:

1. Multiply the value (if any) appearing in the carcinogenic screening level column of the RSL Resident Air Table by ten to produce a residential indoor air carcinogenic screening level at a target cancer risk of 10^{-5} .
2. Select the lower of the 10^{-5} carcinogenic screening level (if any) as calculated above and the value (if any) appearing in the noncarcinogenic screening level column of the RSL Resident Air Table as the IDEM published level for residential indoor air.
3. Delete residential indoor air levels for chemicals with vapor pressures listed as less than 1 millimeter of mercury in the U.S. EPA RSL Chemical-specific Parameters Supporting Table.

IDEM does not include residential indoor air action levels in Table 1. However, they may be calculated by multiplying IDEM's published level for residential indoor air by ten.

A.4.3.2 Commercial Indoor Air Levels

Column eight of Table 1 contains levels for the commercial indoor air exposure scenario. IDEM derives these levels from values appearing in the U.S. EPA RSL Composite Worker Air Table as follows:

1. Multiply the value (if any) appearing in the carcinogenic screening level column of the RSL Composite Worker Air Table by ten to produce a commercial indoor air carcinogenic screening level at a target cancer risk of 10^{-5} .
2. Select the lower of the 10^{-5} carcinogenic screening level (if any) as calculated above and the value (if any) appearing in the noncarcinogenic screening level column of the RSL Composite Worker Air Table as the IDEM published level for commercial indoor air.
3. Delete commercial indoor air levels for chemicals with vapor pressures listed as less than 1 millimeter of mercury in the U.S. EPA RSL Chemical-specific Parameters Supporting Table.

IDEM does not include commercial indoor air action levels in Table 1. However, they are easily calculated by multiplying IDEM's published level for commercial indoor air by ten.

A.4.4 Soil Gas Levels

IDEM publishes six different types of soil gas levels, all expressed in micrograms per cubic meter ($\mu\text{g}/\text{m}^3$). IDEM derives these levels by dividing an indoor air level by an appropriate attenuation factor, as described below. As with indoor air levels, IDEM does not publish soil gas levels for chemicals with vapor pressures listed as less than one millimeter of mercury in U.S. EPA's RSL Chemical-specific Parameters Supporting Table. Qualifiers next to IDEM's published levels for soil gas indicate the following: C = carcinogenic endpoint; N = noncarcinogenic endpoint.

A.4.4.1 Residential: Subslab/Deep Exterior Soil Gas/Conduit Vapor

Column nine of Table 1 contains levels for *residential* subslab, deep exterior soil gas, and/or conduit vapor. IDEM derives these levels by dividing the IDEM published level for residential indoor air by an attenuation factor of 0.03.

A.4.4.2 Commercial: Subslab/Deep Exterior Soil Gas/Conduit Vapor

Column ten of Table 1 contains levels for *commercial* subslab, deep exterior soil gas, and/or conduit vapor. IDEM derives these levels by dividing the IDEM published level for commercial indoor air by an attenuation factor of 0.03.

A.4.4.3 Large Commercial: Subslab/Deep Exterior Soil Gas/Conduit Vapor

Column eleven of Table 1 contains levels suitable for use with large commercial subslab, deep exterior soil gas, and/or conduit vapor results. IDEM derives them by dividing the IDEM published levels for commercial indoor air by an attenuation factor of 0.003. See Section 3.3.4 for lines of evidence that support a large commercial structure designation.

A.4.4.4 Residential: Shallow Exterior/Utility Corridor Soil Gas

Column twelve of Table 1 contains levels for residential shallow exterior and/or utility corridor soil gas. IDEM derives these levels by dividing the IDEM published level for residential indoor air by an attenuation factor of 0.1.

A.4.4.5 Commercial: Shallow Exterior/Utility Corridor Soil Gas

Column thirteen of Table 1 contains levels for commercial shallow exterior and/or utility corridor soil gas. IDEM derives these levels by dividing the IDEM published level for commercial indoor air by an attenuation factor of 0.1.

A.4.4.6 Large Commercial: Shallow Exterior/Utility Corridor Soil Gas

Column fourteen of Table 1 contains levels suitable for use with shallow exterior and/or utility corridor soil gas results obtained beneath or near commercial structures that qualify as large. IDEM derives them by dividing the IDEM published levels for commercial indoor air by an attenuation factor of 0.01. See Section 3.3.4 for lines of evidence that support a large commercial structure designation.

Appendix B: Background

[IC 13-25-5-8.5](#) defines “background levels of hazardous substances and petroleum that occur naturally on the site” as acceptable remediation objectives. For this reason, IDEM does not anticipate requiring a responsible party to implement a remedy to address risks arising from naturally occurring concentrations of chemicals, even if those concentrations exceed IDEM’s published levels.

This appendix provides examples of procedures for deciding whether observed concentrations of chemicals in soil, groundwater, or vapor are attributable to naturally occurring background. Essentially, the procedures described herein compare chemical concentrations found within an area potentially affected by a release to those found in a similar area that is not affected by a release. Comparison of observed concentrations between the areas usually indicates whether a release has occurred.

There are many possible approaches to naturally occurring background evaluations. All of them rely critically on an adequate understanding of the area under evaluation, as reflected in a CSM. IDEM will evaluate each background demonstration on its merits, and for consistency with U.S. EPA guidance (U.S. EPA, 2002e). However, most projects will not require a background or off-site source demonstration. In other cases, it may be possible to rely, at least in part, on pre-existing studies. IDEM recognizes and will consider regional (IDEM 2014, 2017d) or state-wide background studies (Smith et al., 2014). IDEM will evaluate proposals to use data from such studies on a project-specific basis.

B.1 General Approach

The remainder of this appendix is broken into several subsections:

- Soil background, including terminology, sampling considerations, and outlier testing
- Evaluating soil background using judgmentally collected samples
- Evaluating soil background using systematically collected samples
- Evaluating soil background using small sample sets
- Evaluating groundwater background
- Evaluating vapor background
- What IDEM will look for when evaluating background demonstrations

B.2 Background Levels in Soil

The basic procedure for background evaluation in soil involves collecting samples from each of two separate areas and comparing the sample results to see if they differ significantly. The first sample set should come from a background reference area. The second sample set should come from a decision unit.

B.2.1 Soil Background Reference Areas

Soil background reference areas should have physical, chemical, and geological characteristics like those of the decision unit, but have virtually no impacts from the decision unit. IDEM recommends using background reference areas as close as practicable to the decision unit. However, it may be difficult to find a suitable background reference area near some decision units. In some cases, a non-impacted area within a decision unit may be suitable as a background reference area. Because selection of a background reference area is a matter of professional judgment, responsible parties may wish to obtain concurrence on appropriate sampling locations from IDEM staff before collecting background samples.

It is not appropriate to bias the background data by sampling locations suspected to have high concentrations of release-related chemicals. The following may not be suitable as background reference areas:

- Areas where hazardous substances, petroleum, solid or hazardous waste or waste waters are known or suspected to have been managed, treated, handled, stored, or disposed
- Areas affected by roadways or parking lot runoff or road spray when evaluating chemicals associated with motor vehicles
- Railroad tracks, rights-of-way, or other areas affected by their runoff when evaluating chemicals associated with railroads and right-of-way maintenance
- Storm drains or ditches presently or historically receiving industrial or urban runoff
- Fill areas, unless the decision unit under investigation is on similar fill, or IDEM agrees that the fill area is a valid background reference area⁴¹

B.2.2 Soil Background Threshold Values

Sample results from background reference areas are used to calculate a background threshold value (BTV). The BTV is in turn compared against sample data from the decision unit. Appropriate methods for calculating BTVs vary depending on soil sampling methodology and the number of samples collected. IDEM also recognizes that other approaches may be acceptable or even preferable and will evaluate alternative approaches on their merits.

Singh and Maichle (2015) and IDEM recommend a minimum of ten background samples when determining a BTV. More than ten samples may be necessary to calculate a BTV when the laboratory reporting limit is equal to the remediation objective. Investigators should document that the number of samples is adequate to support the selected method in these cases by evaluating the ratio of the minimum detectable difference to an estimate of the standard deviation of the distribution of the concentrations at the decision unit (U.S.EPA 2002). Because the data evaluation process sometimes reduces the size of the set of background samples, it may be prudent to collect extra samples during the initial sampling effort.⁴² Conversely, IDEM recognizes that there are instances in which it is impracticable to collect ten or more samples. Section B.2.6 provides guidance for those circumstances.

B.2.3 Soil Outliers

U.S. EPA (2006b) contains guidance on identifying potential outliers, including selection and application of specific statistical tests for that purpose. The details of those procedures are beyond the scope of this document. Instead, an abbreviated outline of appropriate procedures follows, illustrated in Figure B-1.

Attempts to identify outliers should always bear in mind that sample results that appear to be outliers may represent extreme values of a distribution. For this reason, it is not appropriate to rely solely on graphical and statistical tests to identify outliers. Any decision to drop sample results from a data set "...should be based on judgmental or scientific grounds" (U.S. EPA, 2006b, page 115), such as transcription errors or measurement system errors.

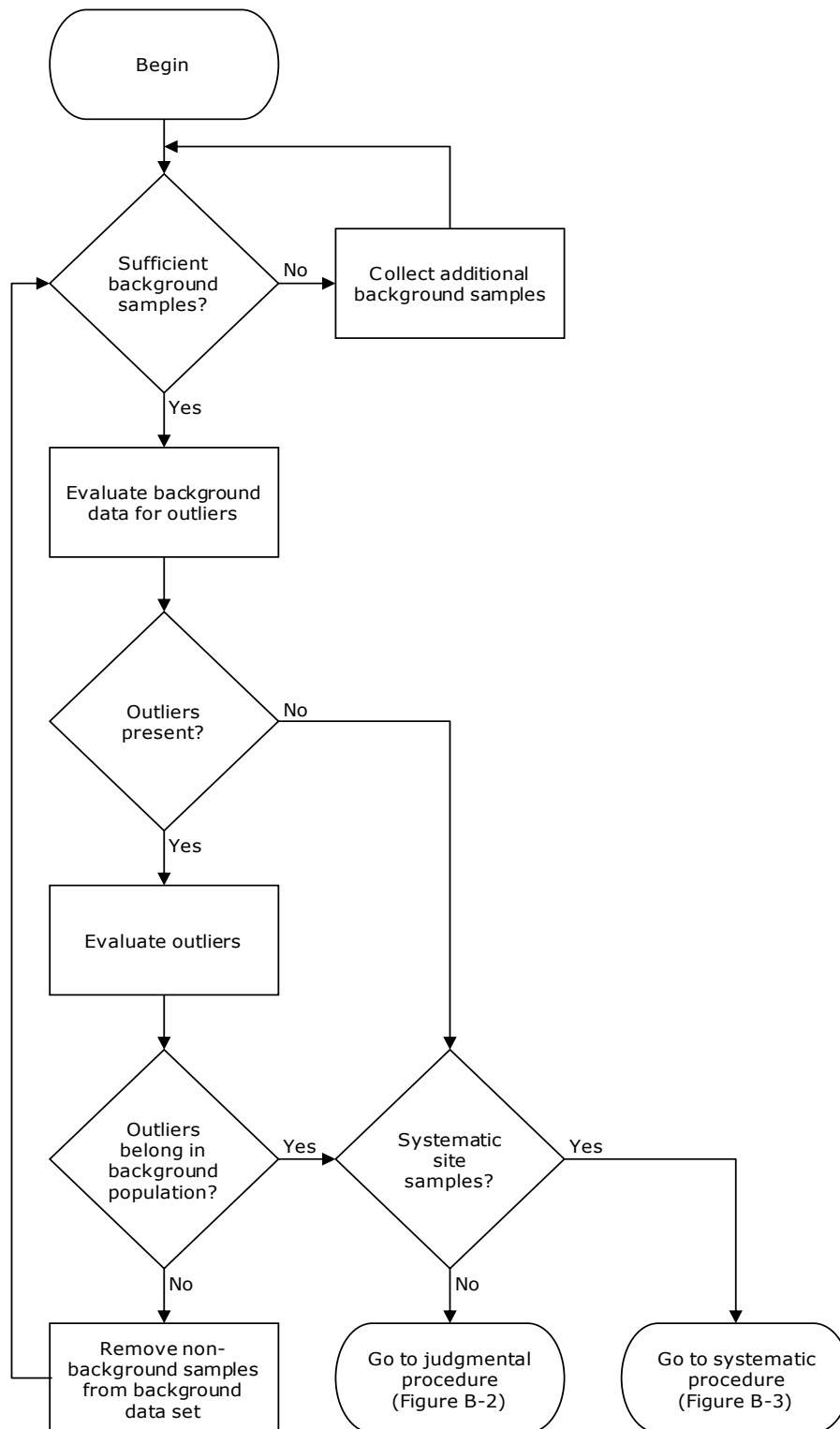
⁴¹ Fill in this context refers only to clean fill or fill that is excluded from the requirements of the solid or hazardous waste management regulations. Waste fill is subject to rule and is beyond the scope of this guidance.

⁴² Sometimes it is possible for the laboratory to hold samples for future analysis, subject to need and method holding times.

Abbreviated Procedure

1. *Collect enough samples from an appropriate background reference area.* Most of the procedures in this guidance call for at least ten samples, though Section B.2.6 describes a procedure for smaller sample sets. Potential issues that could reduce the number of data points include sample collection, handling, and analysis issues; the presence of outliers, or an excessive number of non-detect samples. If the number of data points is insufficient, collect additional samples. Note that in some cases it may be possible to submit more than the needed number of samples to the laboratory and ask that some of them be held pending evaluation of the first set of results.
2. *Screen background sample results for potential outliers.* IDEM recommends using graphical methods for this purpose. Q-Q plots or box-and-whisker plots are often suitable. See U.S. EPA (2006b) for specifics on the construction and interpretation of these plots.
3. *Perform formal outlier tests on any identified potential outliers.* If the background reference area data set contains potential outliers, perform the Dixon Test (U.S. EPA, 2006b) for data sets containing 25 or fewer samples, and Rosner's Test for data sets containing more than 25 samples.
4. *Decide whether outliers identified in step three above belong in the background population.* As noted in the second paragraph of this section, any decision to drop an identified outlier should be based on judgmental and scientific grounds, not merely because of the result of a statistical test.
5. If identified outliers are dropped from the background data set, return to step one above. If identified outliers belong in the background data set, or if there are no outliers present, go to the procedure described in Section B.2.4 for judgmentally collected background reference area samples, and Section B.2.5 for systematically collected background reference area samples.

Figure B-1: Outlier Evaluation



B.2.4 Background Threshold Values Using Judgmental Soil Samples

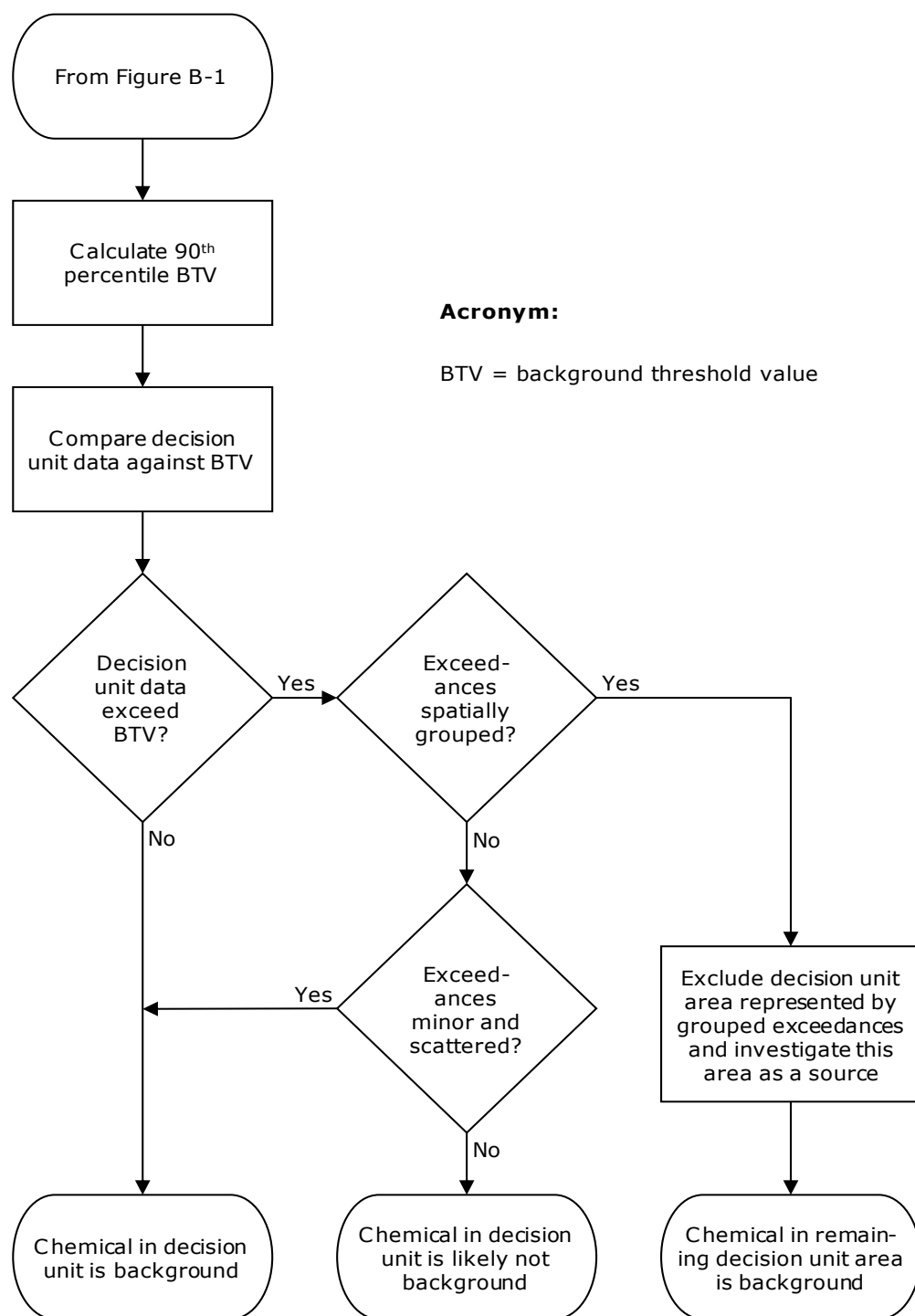
Figure B-2 illustrates an example procedure for comparing a judgmentally collected background data set to decision unit sample results. Under this approach, the BTV is the 90th percentile value, calculated from a set of at least ten background data points, *after addressing outliers* (Section B.2.3). Comparison of the BTV with decision unit data will lead to different conclusions, depending primarily on which concentrations are greater.

Procedure

1. *Calculate the 90th percentile BTV of the background data set.*
 - a. Multiply the number of data points by 0.9 to find the position of the 90th percentile.
Example: 12 data points $\times 0.9 = 10.8$ (position of the 90th percentile)
 - b. Arrange the individual data points in ascending order of their concentration values
Example: 2, 5, 7, 12, 14, 16, 20, 23, 25, 27, 29, 32
 - c. Calculate the concentration corresponding to the 10.8th position as the value of the 10th position plus 80% of the difference between the 10th and 11th values.
Example: $27 + 0.8 \times (29 - 27) = 27 + 0.8 \times (2) = 27 + 1.6 = 28.6 \sim 29$
2. *Compare the BTV to each decision unit sample concentration.*
 - a. If decision unit sample concentrations are no greater than the BTV, the decision unit concentrations are background.
 - b. If decision unit sample concentrations include only scattered, minor, and non-spatially grouped exceedances of the BTV, then the decision unit concentrations may be background.
 - c. If decision unit sample concentrations include spatially grouped exceedances, treat the area defined by those exceedances as a potential source area, and characterize it accordingly. The portion of the decision unit that does not exceed the BTV can be regarded as background.
 - d. If decision unit sample concentrations exceed the BTV, concentrations in the decision unit are likely not background.

IDEM will evaluate alternative approaches consistent with U.S. EPA (2002e) and Singh and Maichle (2015).

Figure B-2: Background Threshold Values Using Judgmental Sampling



B.2.5 Background Threshold Values Using Systematic Soil Samples

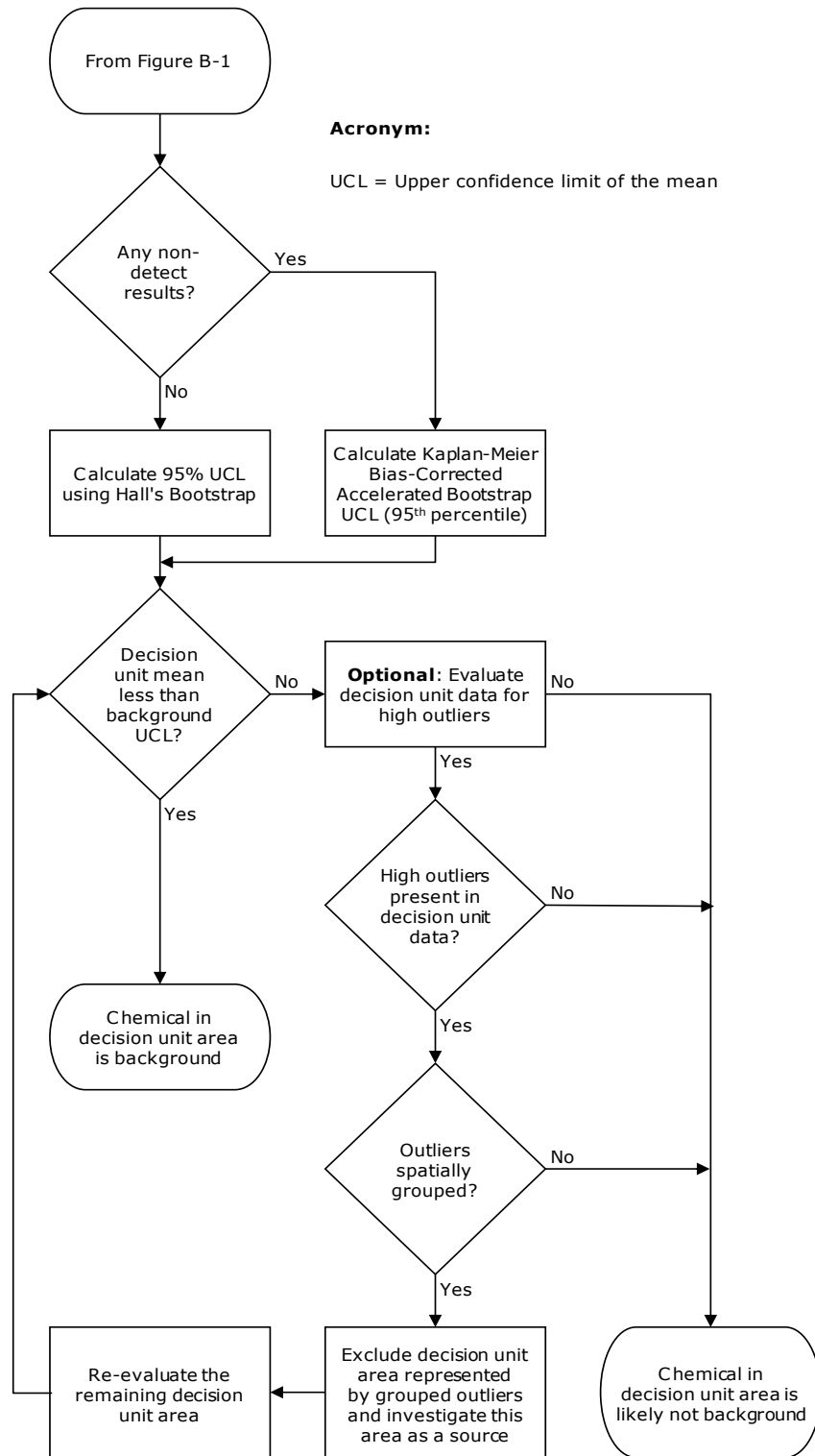
U.S. EPA's ProUCL software includes background comparison tools that are useful for comparing decision unit samples to systematically collected background samples. ProUCL applies several methodologies to each analysis and then recommends an appropriate statistic depending on the characteristics of the data. Alternatively, the rest of Subsection B.2.5 describes an example procedure for comparing a systematically collected background data set to decision unit samples. Figure B-3 illustrates the procedure, which follows the outlier procedures described in Section B.2.3.

Procedure

1. For background data sets with non-detect values, calculate the 95th percentile Kaplan-Meier Bias-Corrected Accelerated Bootstrap UCL using 10,000 bootstrap operations, and use the resulting UCL as the BTV. For background data sets without non-detect values, calculate the 95% UCL using Hall's Bootstrap, and use the resulting UCL as the BTV.
2. Compare the BTV calculated in step one above to the arithmetic mean of the decision unit sample results.
 - a. If the arithmetic mean of the decision unit samples is less than the BTV, then the chemical in the decision unit is background.
 - b. If the arithmetic mean of the decision unit samples is greater than the BTV, either
 - i. Conclude that the chemical in the decision unit is not background, or
 - ii. Evaluate the decision unit sample results for high outliers.
 - A. If there are no high outliers in the decision unit sample results, the chemical in the decision unit is not background.
 - B. If there *are* high outliers in the decision unit data, determine whether those outliers are spatially grouped.
 - α. If the high outliers are not spatially grouped, the chemical in the decision unit is not background.
 - β. If the high outliers are spatially grouped, carve out the area defined by those outliers and investigate it as a source. Then re-evaluate the remainder of the decision unit, beginning with Step 2, above.

IDEM will evaluate other approaches consistent with U.S. EPA (2002e) and Singh and Maichle (2015).

Figure B-3: Background Threshold Values Using Systematic Sampling



B.2.6 Background Evaluations Using Small Soil Data Sets

Some remediation projects have trouble getting enough background samples to calculate a statistically based BTV. This is often due to a scarcity of suitable background reference areas. This subsection describes an example procedure for obtaining BTVs from small background sample sets. Figure B-4 illustrates the procedure in decision tree format.

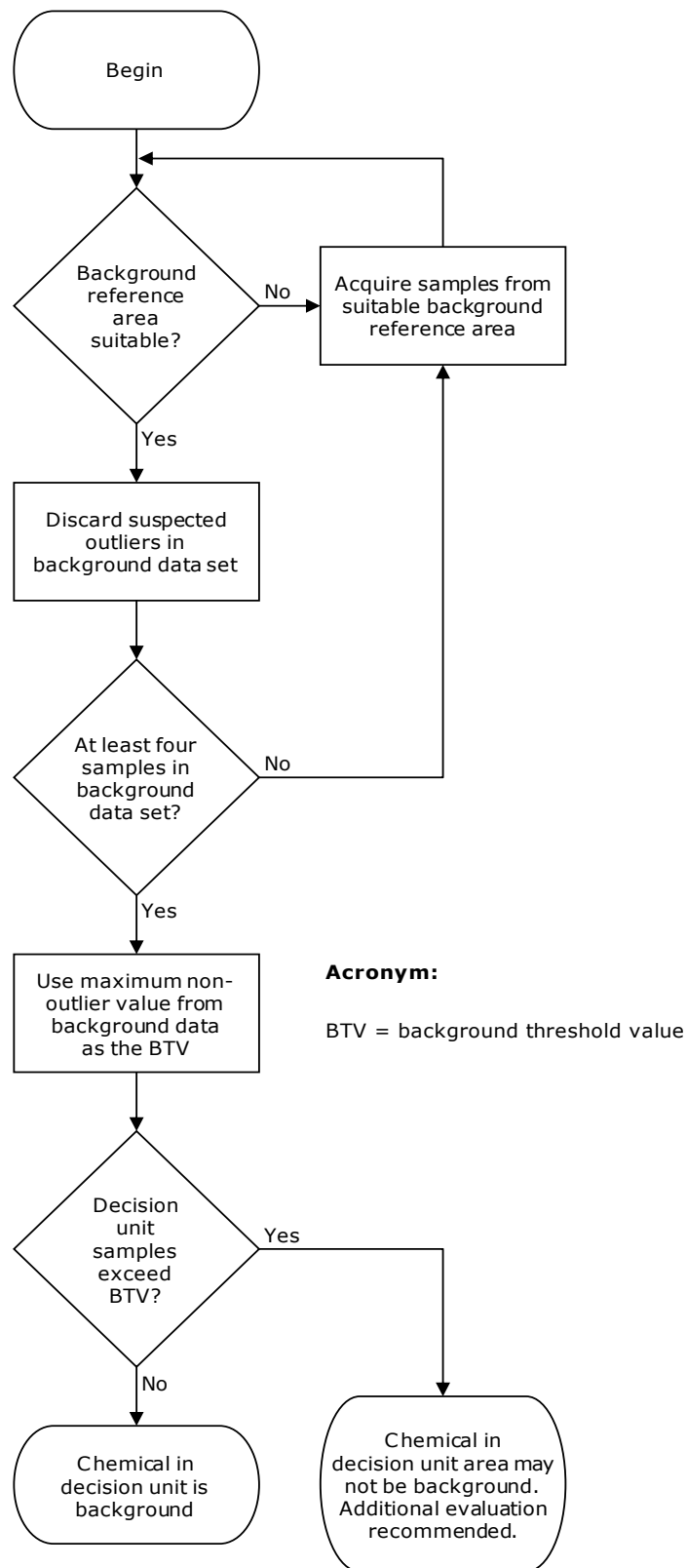
Procedure

1. Use criteria described in Section B.2.1 to decide whether the proposed background reference area is appropriate. If it is not, select an appropriate background reference area and collect sufficient samples from that area. Otherwise, continue to Step 2.
2. Use a Q-Q plot to screen background reference area samples for outliers. If the Q-Q plot reveals one or more potential outliers, use Dixon's test on those outliers. Discard identified outliers that meet the criteria described in Section B.2.3.
3. If fewer than four background reference area sample results remain, collect additional background reference area samples, and return to Step 2. Otherwise, designate the maximum non-outlier value from the background reference area samples as the BTV.
4. Compare the BTV against each decision unit sample result for the same chemical. If decision unit sample concentrations do not exceed the BTV, then the decision unit is background. Otherwise, the decision unit may not be background, and further characterization of the decision unit may be necessary.

B.2.7 Background in Soil: Other Approaches

Singh and Maichle (2015) identify additional procedures for the BTV comparison to decision unit samples, including use of two-sample hypothesis testing and graphical methods to compare two or more populations. IDEM will evaluate alternative proposals consistent with U.S. EPA (2002e) and Singh and Maichle (2015).

Figure B-4: Background Evaluation using Small Background Sample Sets



B.3 Background Levels in Groundwater

As with soil, the basic procedure for background evaluation in groundwater involves collecting samples from each of two different areas and comparing the sample results to see if they differ significantly. The first sample set should come from a groundwater background reference area. The second sample set should come from a decision unit. What follows is an example procedure (illustrated in decision tree form in Figure B-5) for evaluating background levels in groundwater. IDEM will evaluate alternative procedures on their merits.

Procedure

1. Collect eight or more quarters of data from appropriate groundwater locations, as described in Section B.3.1.
2. If there is more than one groundwater sampling location in the background reference area, it may be advantageous to pool the background data to minimize the number of necessary comparisons with decision unit groundwater sample results. To do this, calculate the root mean square deviation (RMSD) of the data from each background well (Equation B-1, below) and check to see if the RMSD is no greater than 1.3. If so, data pooling is appropriate. If not, either consult with IDEM regarding next steps, or proceed without pooling the data.
3. If there are non-detect values in the background data set (pooled or not), calculate the 95% UCL using the Kaplan-Meier Bias-corrected Accelerated Bootstrap and use that as the groundwater BTV. If there are no non-detect values in the background data set (pooled or not), calculate the 95% UCL using Hall's Bootstrap, and use that as the groundwater BTV.
4. Compare the BTV determined above with the arithmetic mean of groundwater data from the decision unit. If the arithmetic means of groundwater data from all the monitoring wells within the decision unit are less than the BTV, the decision unit is not a source. Otherwise, the decision unit may be a source, and further characterization or a remedy is necessary.

Equation B-1: Root Mean Square Deviation

$$\text{RMSD} = \sqrt{\frac{\sum_{i=1}^n (C_{ai} - C_{wi})^2}{N}}$$

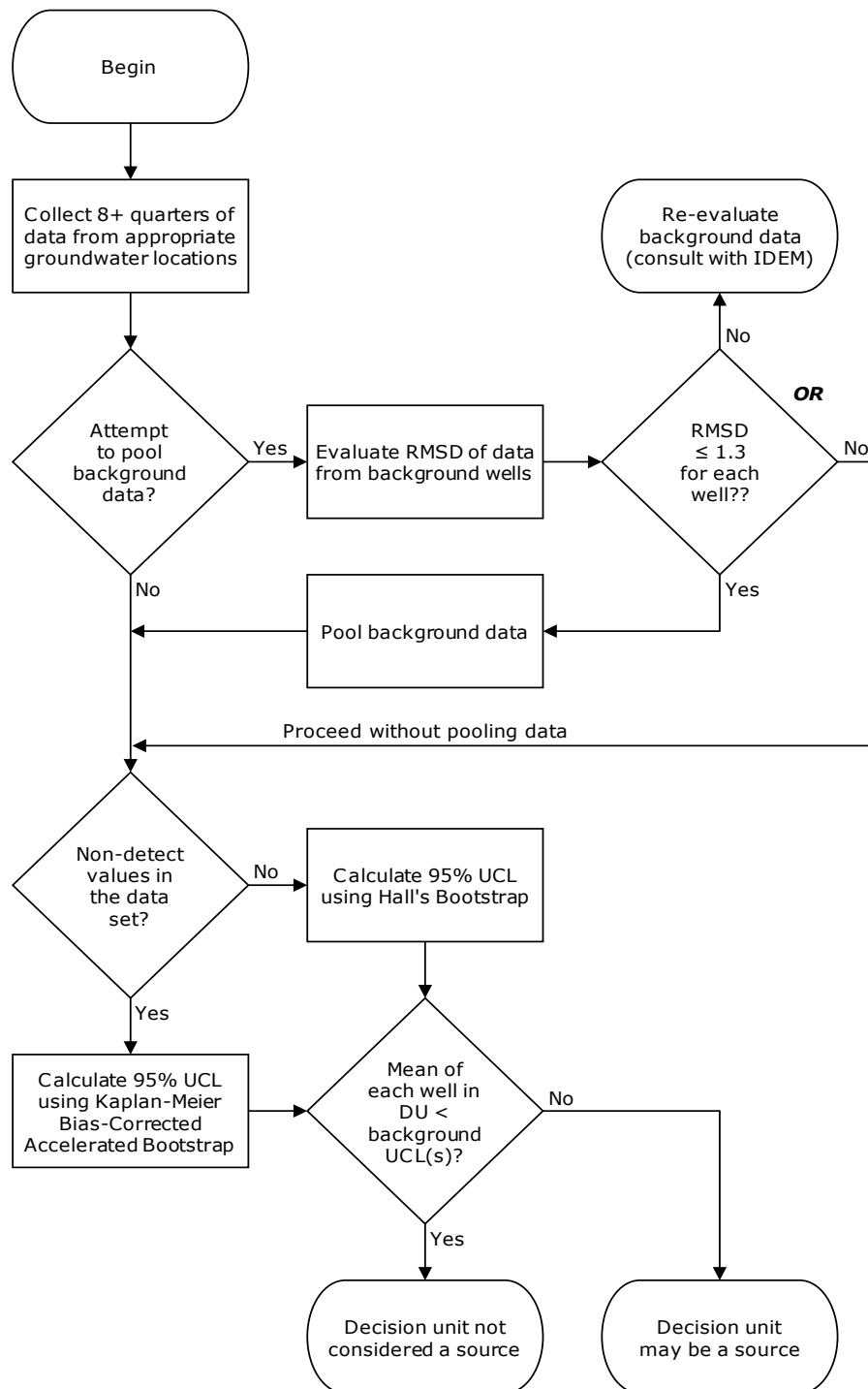
Where:

C_{wi} = the concentration of a chemical for a given sampling event in the well currently under evaluation

C_{ai} = the average concentration of that chemical in those background wells not currently under evaluation. For example: if there are four background wells and well 2 is currently under evaluation, this value is the average of that chemical's concentrations in wells 1, 3, and 4; and

N = the total number of background wells.

Figure B-5: Groundwater Background Evaluation



Acronyms:

DU = Decision unit
 RMSD = Root mean square deviation
 UCL = Upper confidence limit of the mean

B.3.1 Appropriate Groundwater Sampling Locations

Appropriate groundwater background sampling points are typically upgradient of, and hydraulically connected to, the decision unit. Background sampling placement should consider the following hydrogeologic assumptions:

- The groundwater background samples are from areas unaffected by any release(s) that affect(s) the decision unit
- The upgradient and downgradient well samples are drawn from the same aquifer and the wells are screened at approximately the same hydrostratigraphic position. The fate and transport characteristics of chemicals dissolved in groundwater likely will differ in each aquifer, resulting in unique concentration patterns.
- The groundwater flows in a definable path from upgradient to downgradient wells beneath the area under investigation (undefined or incorrectly defined flow paths may invalidate statistical comparisons)
- The groundwater flow moves at a sufficient velocity beneath the decision unit, so that the same groundwater observed at upgradient well locations is subsequently monitored at downgradient wells over the course of the evaluation
- The time between sampling events and velocity of the groundwater flow is sufficient to ensure collection of independent samples

To minimize sampling variability, collect all groundwater samples using the same or similar sampling equipment and methods. Because groundwater moves, background evaluations in groundwater take more time than soil evaluations. Sampling over time also allows for evaluation of fluctuations in observed concentrations caused by climate and rainfall. Collect a minimum of eight quarterly samples from each well used in the evaluation.

Clustered or spatially correlated sampling results can skew background statistics. Geospatial methods address this problem by better representing background concentrations that vary spatially. The products of the analysis can be measurements of spatial correlations of existing data, as well as an estimate of the true background population statistical distribution when working with spatially correlated data. For more information, see ITRC (2016) for discussion on using geospatial results in background estimation.

B.4 Background Levels in Vapor

IDEM is not aware of naturally occurring sources of significant ambient air concentrations of the chemicals (chlorinated solvents and benzene) that typically drive *release-related* indoor air risk. For this reason, IDEM does not provide detailed guidance on demonstrating the existence of naturally occurring ambient background in vapor. Any such demonstrations will have to be project-specific, and IDEM will evaluate them based on the characteristics of the demonstrations.

B.5 How IDEM Will Evaluate Background Level Demonstrations

Soil

- Does the soil background reference area have physical, chemical, and geological characteristics like that of the decision unit under evaluation?
- Is the background reference area free of impacts from releases?
- Has the background reference data been screened appropriately for outliers?
- Were there enough background data points collected to meet the DQO?
- Is a reasonable rationale provided for dropping any outliers from the background threshold data set?
- Have spatially grouped outliers been identified for further investigation as a potential source area?
- Are there sufficient sample results to perform relevant statistical tests?
- Were background threshold values calculated appropriately?
- Were appropriate conclusions drawn from comparison of the background threshold value and data from the decision unit(s)?

Groundwater

- Is the groundwater background reference area unaffected by releases?
- Are groundwater background reference area and decision unit wells drawn from the same aquifer and screened at approximately the same hydrostratigraphic position?
- Does groundwater flow in a definable path from upgradient to downgradient wells?
- Is groundwater flow velocity sufficient so that the same groundwater observed at upgradient well locations is subsequently observed at downgradient wells during the evaluation?
- Is groundwater flow velocity sufficient to ensure collection of independent quarterly samples from any given well?
- Are there enough sample results to perform the relevant tests?
- Were enough background data points collected to meet DQOs?
- Was the groundwater background data shown to be independent and identically distributed?
- If groundwater background data pooling is proposed, is the root mean square deviation of the background well data no greater than 1.3?
- Is the groundwater background threshold value based on an appropriate upper confidence limit, considering whether the background data set contains nondetect values?
- Were appropriate conclusions drawn from comparison of the background threshold value and data from each monitoring well in the decision unit?

Vapor

- IDEM evaluation of vapor background demonstrations will be highly dependent on the characteristics of the demonstration

Appendix C: Plume Trend Analysis

Measuring spatial and temporal concentration changes within a plume can be a strong line of evidence that a plume of a release-related chemical in groundwater is behaving consistently. Analysis of these spatial and temporal concentration changes requires a minimum of eight quarters of data from wells that are placed in the same flow zone, within the release-related chemical plume, and in locations that allow an understanding of plume behavior. The location of the monitoring wells is described below and depends upon the type of plume behavior under evaluation. Analysis of the temporal and spatial change in concentration is not necessary at well-understood releases and should be considered only if existing lines of evidence fail to show adequately predictable plume behavior. A list of known acceptable analysis methods that analyze the spatial change appears below. IDEM will evaluate other methods on a case-by-case basis.

C.1 General Approach

If release-related chemicals are present in groundwater at concentrations that exceed unconditional remediation objectives, it is necessary to understand the likely behavior of the plume of each release-related chemical over time. However, evaluation of plume behavior may be premature or even unnecessary if:

- The nature and/or extents of the plume are still under investigation
- Active remediation is occurring
- The short-term objective is to reduce concentrations of release-related chemicals to levels less than unconditional remediation objectives
- Release-related chemicals are moving onto the facility from another source

Statistical Analysis

Statistical plume trend analysis is a temporal line of evidence that combines groundwater monitoring data with regression analysis, time-trend analysis, and other statistical tests from a representative groundwater monitoring well network to demonstrate an increasing, decreasing, or consistent plume. However, appropriate spatial application of statistical plume trend analysis requires a comprehensive well network (as described in each appropriate method listed below), *at least* two years (8 quarters) of consistent data collection, and periodic reassessment of plume conditions during the plume trend analysis. If conditions change during that time, previously installed wells may no longer produce samples that adequately represent the plume, thereby invalidating the statistical analysis. Consistent behavior across the plume, normally a sign of a mature plume, is a stronger line of evidence than individual well results. Independent statistical analysis of individual wells does not normally provide sufficient evidence of plume behavior – a statistical analysis of data from a well network is required.

When considering statistical analysis of plume behavior, consider the following:

- There are multiple trend test methods. The appropriate test depends on several factors, most notably the statistical distribution of the underlying data. If the data appears to fit a predictable distribution, such as normal or lognormal, then a more powerful trend test, such as ordinary least squares regression, can be used. Non-parametric tests like Mann-Kendall or Theil-Sen are appropriate for data that does not fit a known distribution.
- Parametric tests are often more powerful than nonparametric tests. However, as noted above, parametric tests require normal or transformed normal data.
- A statistical test may not be representative if the CSM is incomplete. If wells are not in locations that allow a representative sampling of the plume (same flow zone, in the plume, and in locations described below), data from those wells could provide misleading statistical results.

C.2 Time-Trend Analysis

All else equal, the past behavior of a mature plume is a good indicator of future behavior. This explains the emphasis U.S. EPA (2009) places on monotonic long-term temporal trends (over at least eight quarters) in plume behavior. Monitoring well network design is critical to evaluate spatial variability, and consultation with IDEM technical staff is recommended to ensure that the monitoring well network is appropriate for the demonstration.

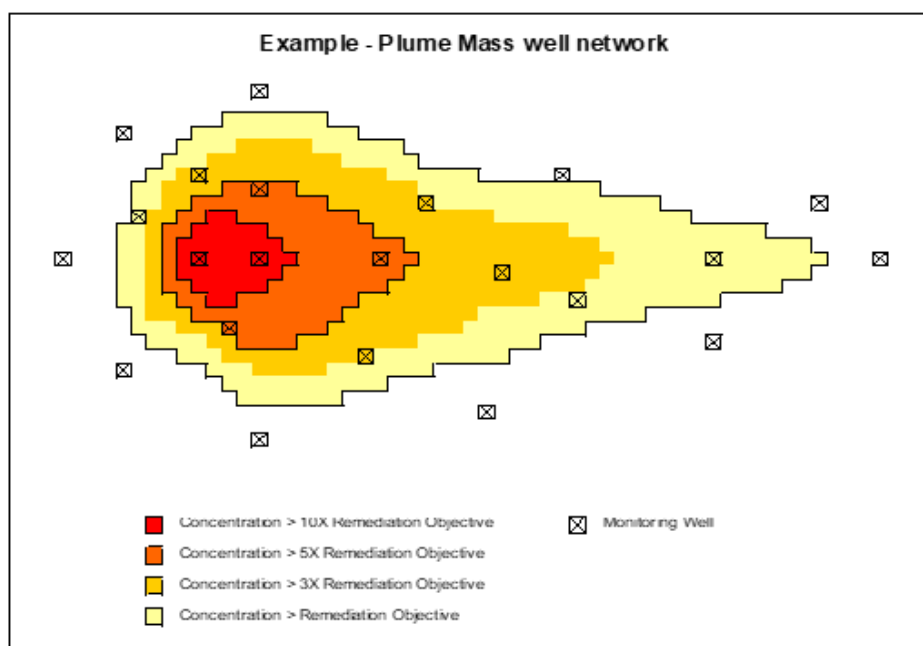
Plume Trend Analysis: Plume Mass

Estimating plume mass requires a three-dimensional understanding of dissolved chemical concentrations at a resolution that allows observation of changes in the overall plume mass. This demonstration may require an extensive groundwater monitoring network, including sampling points at multiple depths so that it is possible to understand how dissolved concentrations vary vertically. In some cases, it may be possible to use knowledge of the subsurface to interpolate between sampling points. A Mann-Kendall evaluation that uses at least eight quarters of calculated relative mass data can provide a high level of confidence in the expected behavior of the plume. In general, more data will increase the value of this line of evidence.

The extent of the necessary monitoring well network will vary by project. Consultation with IDEM technical staff is recommended to ensure that the monitoring well network is appropriate for the demonstration. IDEM recommends beginning with a regression analysis and concluding with a Mann-Kendall analysis of the change in mass over time [U.S. EPA (2009, Chapter 17.3); U.S. EPA (2006b, Step 4.3); Ricker (2008)]. However, IDEM will evaluate alternative statistical demonstrations on a project-specific basis.

After eight independent samples are collected at each monitoring well in a network that adequately covers the extents of the plume, a successful demonstration of decreasing plume mass will show that the relative mass over time has a negative slope or S-value (depending on the statistical method used).

Figure C-1: Illustration of Plume Mass Well Network



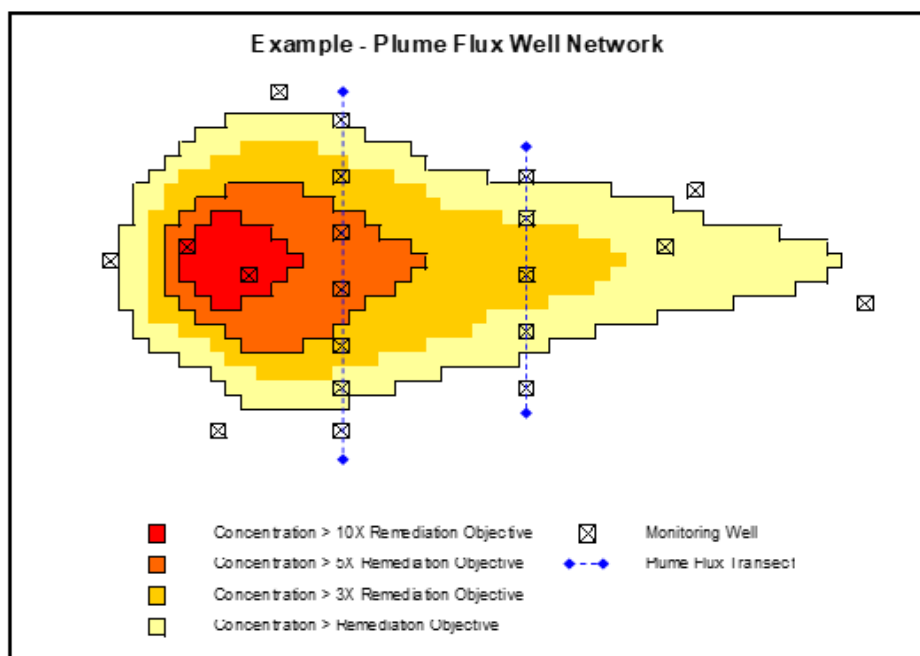
Plume Trend Analysis: Plume Flux

Plume flux is a measurement of change in dissolved chemical concentrations across a plane. Examining the trend in plume flux across one or more projected planes is a useful way to evaluate release-related chemical movement (Figure C-2). However, as with plume mass, complete and accurate characterization of flux may require a substantial monitoring well network that includes multiple transects across the plume at multiple sampling depths. In some cases, it may be possible to use knowledge of the subsurface to interpolate between sampling points. A Mann-Kendall evaluation of the calculated relative mass flux at each transect based on at least eight quarters of data can provide a high level of confidence in the expected behavior of the plume. Plume flux measurements using more sampling data will increase the weight of this line of evidence.

Consultation with IDEM technical staff is recommended to ensure that the monitoring well network is appropriate for the demonstration. Plume flux analysis supplements the plume mass line of evidence with additional statistical evaluations. IDEM recommends beginning with regression analysis for each transect and concluding with Mann-Kendall analysis for each transect [U.S. EPA (2009, Chapter 17.3); U.S. EPA (2006b, Step 4.3); ITRC (2010); Ricker (2008)]. However, IDEM will evaluate alternative statistical demonstrations on a project-specific basis.

After eight independent samples are collected at each monitoring well in at least two transects across the plume, a successful demonstration of decreasing plume flux will show that the relative flux over time has a negative slope or S-value (depending on the statistical method used).

Figure C-2: Plume Flux Well Network



Plume Trend Analysis: Multiple Sample Location Statistical Analysis

This line of evidence combines monitoring data with regression analysis, time-trend analysis, and other statistical tests from a representative groundwater monitoring well network to demonstrate the existence of a significant trend in the concentration in a plume. This method requires a comprehensive well network, multiple years of consistent data collection, and periodic reassessment to be applied appropriately. A Mann-Kendall evaluation of the concentrations at each monitoring well for at least eight quarters provides a pattern for the individual wells. However, independent statistical analysis of each well will not normally provide the necessary evidence of plume behavior. A high level of confidence in the expected behavior of the plume is demonstrated when characteristics are consistent across relevant monitoring wells.

Other lines of evidence are often more directly applicable to well-characterized sources (e.g., age of the plume). By analyzing these other lines of evidence first, it may be possible to evaluate the plume behavior without using statistics (See Section 2.3.5.3). The process of assessing ambient plume trends should be postponed until all active remediation is completed.

A demonstration via this method that a plume is decreasing provides a high level of confidence that risks are decreasing. Conversely, an increasing plume warrants additional investigation and/or a remedy. This demonstration involves evaluating the trend of multiple sampling locations with multiple observations; all else equal more data will increase the weight of this line of evidence. Demonstrating plume behavior is unlikely when at least two of the plume monitoring wells exhibit statistically significant different trends (increasing and decreasing), or when other characteristics are not consistent across relevant monitoring wells.

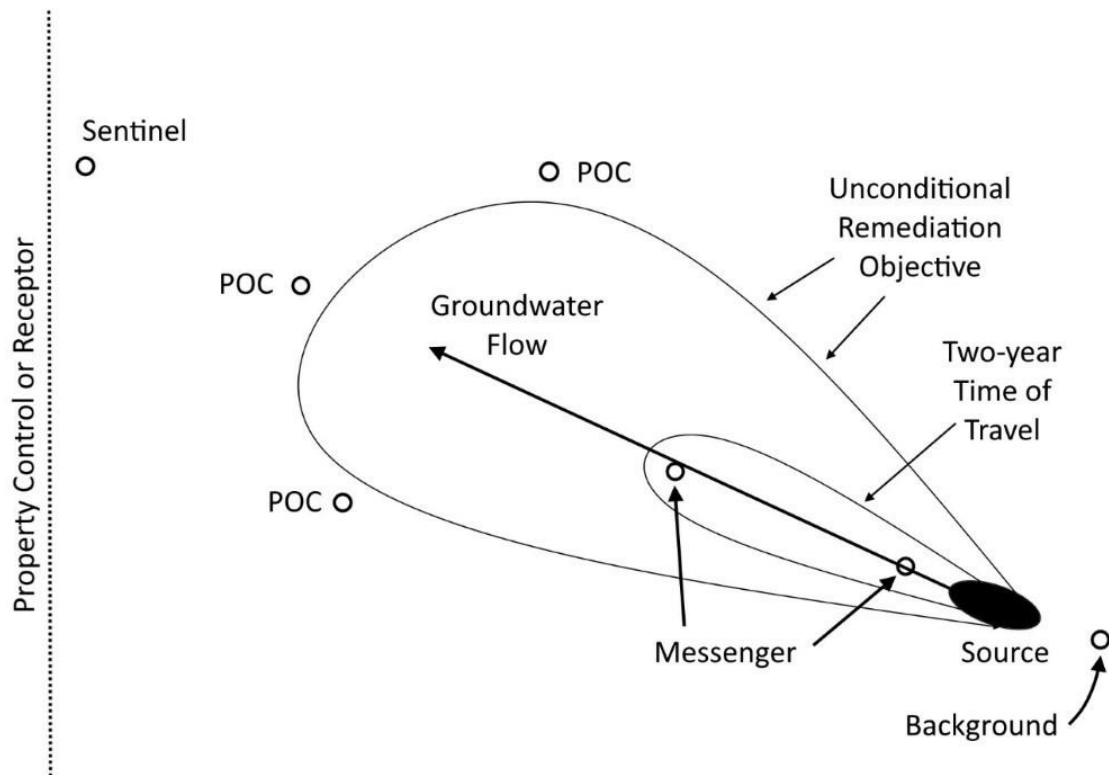
Some wells must be located within specific groundwater time-of-travel distances from the source and show some form of correlation. Before installing wells, estimate the advective flow velocity of groundwater at the decision unit to ensure that the new wells will meet groundwater time-of-travel requirements. This approach will allow sufficient time during monitoring to ensure that groundwater from the closure area reaches key monitoring wells.

Well locations are important when estimating likely future extents. How the monitoring wells relate to one another is used to evaluate the spatial component of the plume. If all the monitoring wells within the plume exhibit approximate trends in the same direction with comparable slopes, then a single summary statement across the well network is valid (U.S. EPA 2006b). If the time-trends do not show a consistent pattern, it is likely that one or more wells are not screened in the same flow zone, or a previously unknown source may be affecting the observed concentrations. In either of these cases, new wells may be necessary to understand plume behavior.

Data on chemical concentrations levels and aquifer characteristics should come from wells and boreholes capable of providing a clear three-dimensional picture of the hydrogeologic and geochemical characteristics of the location. If the wells do not meet appropriate criteria, or if conditions change, previously installed wells may no longer produce samples that adequately represent the plume. In such cases, new wells may be necessary.

The statistical analysis of multiple sample locations requires properly designed, located, and installed groundwater monitoring wells. Figure C-3 depicts a typical likely future extents demonstration well network.

Figure C-3: Plume Monitoring Network



Messenger Wells are in the internal area of the plume, downgradient from the source, and within the two-year groundwater time-of-travel distance from the source. At least one messenger well must be adjacent to the source, and a second messenger well must be between the first messenger well and the two-year groundwater time-of-travel distance of the plume. Most groundwater closure demonstrations use two to four messenger wells. Large or multi-lobed plumes may require more messenger wells. Messenger wells should be (1) as near to the center flow line or flow path as possible and (2) in an area where the release-related chemical concentration is likely to be highest and significantly exceed remediation objectives.

Perimeter of Compliance (POC) wells (at least three) are part of the network, located hydraulically downgradient and/or side-gradient from the messenger wells, where:

- Dissolved concentrations of release-related chemicals will likely exceed reporting limits for at least 75 percent of the monitoring events
- Concentrations of release-related chemicals approximate unconditional remediation objectives
- It is possible to monitor the plume after it has passed through the source and messenger well areas

Install **sentinel wells** to define the extents of the plume and to evaluate the potential risk to downgradient receptors. Locate sentinel wells hydraulically downgradient from POC wells and along a line between the source and any potential receptors. Though sentinel wells are highly useful for signaling an expanding plume, they may be unnecessary if there are substantial lines of evidence to demonstrate that there is no unacceptable risk to a downgradient receptor.

Place **background wells** upgradient of the area of concern and out of the zone of influence of the source. Background wells are essential to understanding upgradient groundwater conditions. If both upgradient and downgradient concerns exist at a decision unit, at least one background well is necessary.

CSM development may require further characterization of plumes through additional groundwater monitoring and assessment of spatial and temporal data trends (e.g., plume area, chemical concentrations, chemical mass, and the center of mass over time). Evaluating the time trend of the wells individually may not provide sufficient information to adequately estimate likely future extents.

Assessment of how the trends relate to each other helps understand plume behavior, and the potential for chemicals to migrate beyond the exposure control area.

Statistical analysis methods may be acceptable when IDEM accepts the characterization and agrees that the CSM is adequately developed. In addition, information from the statistical plume trend analysis can also be used to further refine the CSM. The ProUCL statistical package (Singh and Maichle, 2015) or similar software can evaluate the data used for trend analysis, as well as evaluate the trends in the data.

Standards for such tests (e.g., Mann-Kendall or Theil-Sen) should include the following:

- No well described in the monitoring well network (Figure C-3) can have an increasing trend at a significance level greater than five percent
- After eight independent samples are collected at each monitoring well in the network, only one source well can have a positive slope or S-value.

If the analysis cannot meet both standards, additional lines of evidence are needed to establish stable plume behavior. Additional lines of evidence can include further quarterly groundwater monitoring unless any messenger or perimeter of compliance well shows an increasing trend at a 5% level of significance.

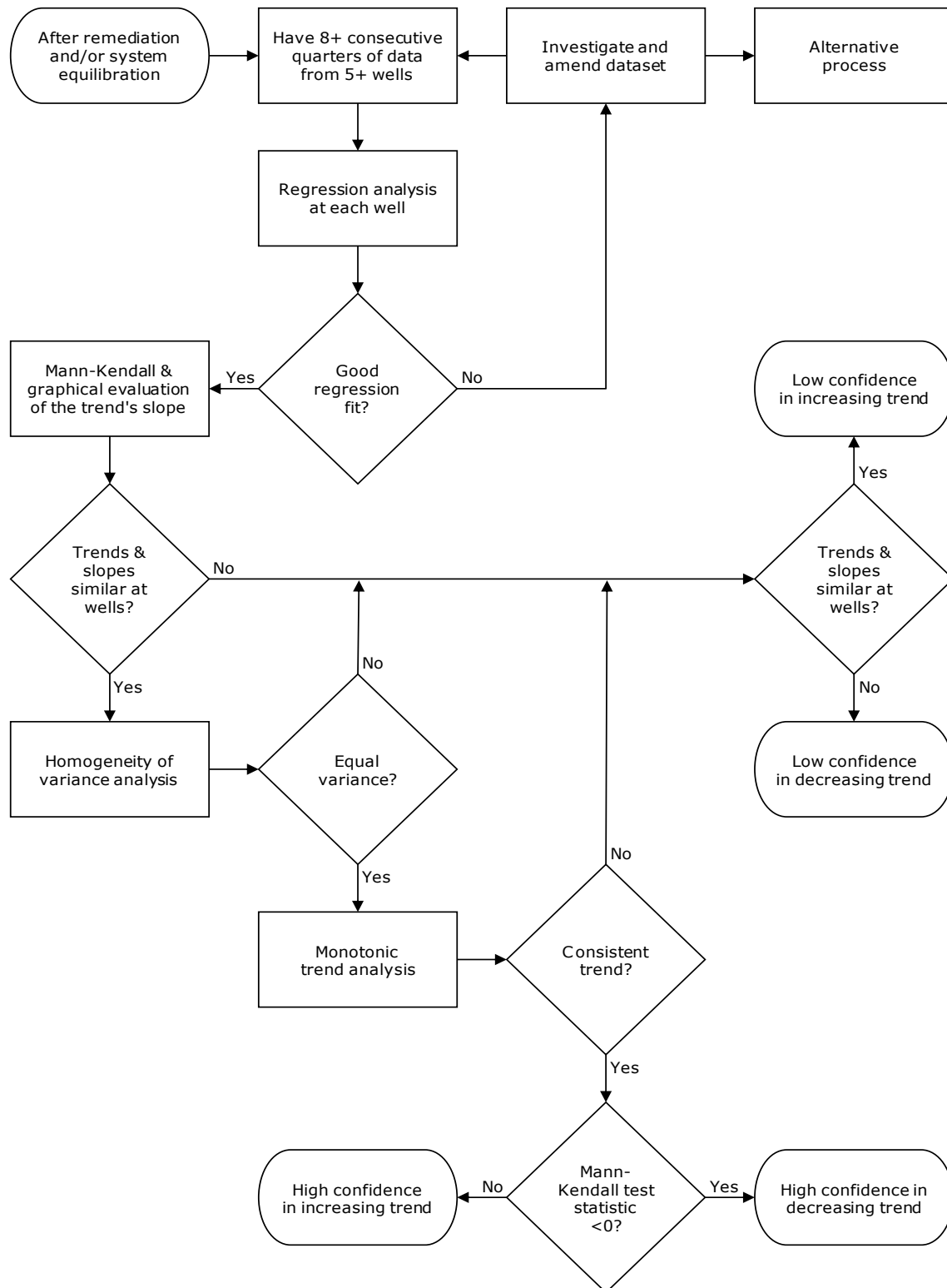
If hydraulic conductivity, saturated thickness, flow gradients, or other important characteristics vary significantly over the evaluation area, it may prove difficult or impossible to confidently predict plume behavior. Similarly, preferential pathways (e.g., karst conditions, fracture flow, utility backfill, etc.) that control groundwater flow and chemical migration complicate estimation of likely future extents. Where this is the case, understanding plume behavior may require assessment of lines of evidence that are not covered in this Appendix (see Section 2.3.5.3).

U.S. EPA (2006b) describes various methods for evaluating trends of different combinations of spatial and temporal data. If there is widespread variation within the plume, IDEM may request the statistical analysis depicted in Figure C-4 and explained in a 5-step process.

- Step 1: Regression analysis of data from each well
- Step 2: Mann-Kendall trend analysis of data from each well
- Step 3: Graphical demonstration that data from each well exhibits similar trends and slopes
- Step 4: Homogeneity of variance analysis
- Step 5: Monotonic trend analysis

IDEM will evaluate other plume trend analysis methods on their merits.

Figure C-4: Example of Plume Trend Analysis



C.3 Modeling Plume Behavior

Groundwater modeling may be helpful when attempting to predict the future extents of release-related chemical plumes. Groundwater modeling is inherently project-specific and will typically require geologic and hydrologic parameter values in addition to knowledge of release-related chemical behavior. IDEM review of groundwater modeling results will require that submissions include information on the model used (including any version number), all model inputs, assumptions, calibration results, validation results, and the results of sensitivity testing.

Appendix D: Ecological Risk Evaluation

Ecological risk evaluation is a potentially complex process, and a full treatment of the topic is beyond the scope of this document. This appendix sketches the outline of an ecological risk evaluation process and lists references that provide additional guidance on ecological risk evaluation. The process begins with the simplest and least resource-intensive type of evaluation and progresses, when appropriate, into progressively more complex and resource-intensive procedures:

- Step 1 Determine if ecologically significant areas are present near the release (Section D.2). Use existing information to determine whether release-related chemicals have reached, or are reasonably likely to reach, ecologically important areas (Section D.2). If not, there is no need for further ecological risk evaluation. If yes, proceed to Step 2.
- Step 2 Use relatively limited sampling data and generic ecological screening levels to determine whether further ecological risk evaluation is necessary (Section D.3). If not, there is no need for further ecological risk evaluation. If yes, proceed to Step 3.
- Step 3 Refine the screening levels based on project-specific conditions. This usually involves estimating doses received by species that represent specific ecosystem guilds and comparison of those doses against specific criteria. Decide whether an ecological remedy is necessary. This is a potentially iterative process (Section D.4).

IDEM anticipates that the first step listed above will be adequate for most releases, and that the percentage of releases proceeding through the process will diminish with each successive step. In some cases, it may be obvious that an ecological remedy is necessary. When that is true, it is acceptable to proceed directly to implementation of an appropriate interim ecological remedy.

D.1 Basis for Requiring Ecological Risk Evaluation

Ecological risk evaluation is necessary to determine per [IC 13-25-5-8.5\(c\)](#) whether additional action is necessary to protect the environment. IDEM has determined that Step 1 above is likely to suffice for most releases. Sections D.3 and D.4 provide additional guidance for those releases where additional ecological evaluation proves necessary.

D.2 Preliminary Ecological Risk Evaluation

Current and historic facility operations and environmental setting are important to consider when evaluating potential ecological risk. Every CSM should set the stage for a preliminary evaluation of the potential for ecological risk. IDEM anticipates that in most cases, an adequate discussion of potential ecological risk will be relatively brief – generally a few paragraphs or less – and that information collected during routine CSM development will usually suffice to decide whether release-related chemicals are reasonably likely to reach ecological receptors.

A process diagram (Figure D-1) illustrates an approach to answering this question. It starts by asking whether the extents of release-related chemicals are restricted to areas *not* subject to ecological risk evaluation (**exempt areas**). Such areas might include the following:

- Paved areas, including paved drainage ditches
- Buildings and associated landscaping
- Other areas characterized by intensive development
- Tilled land

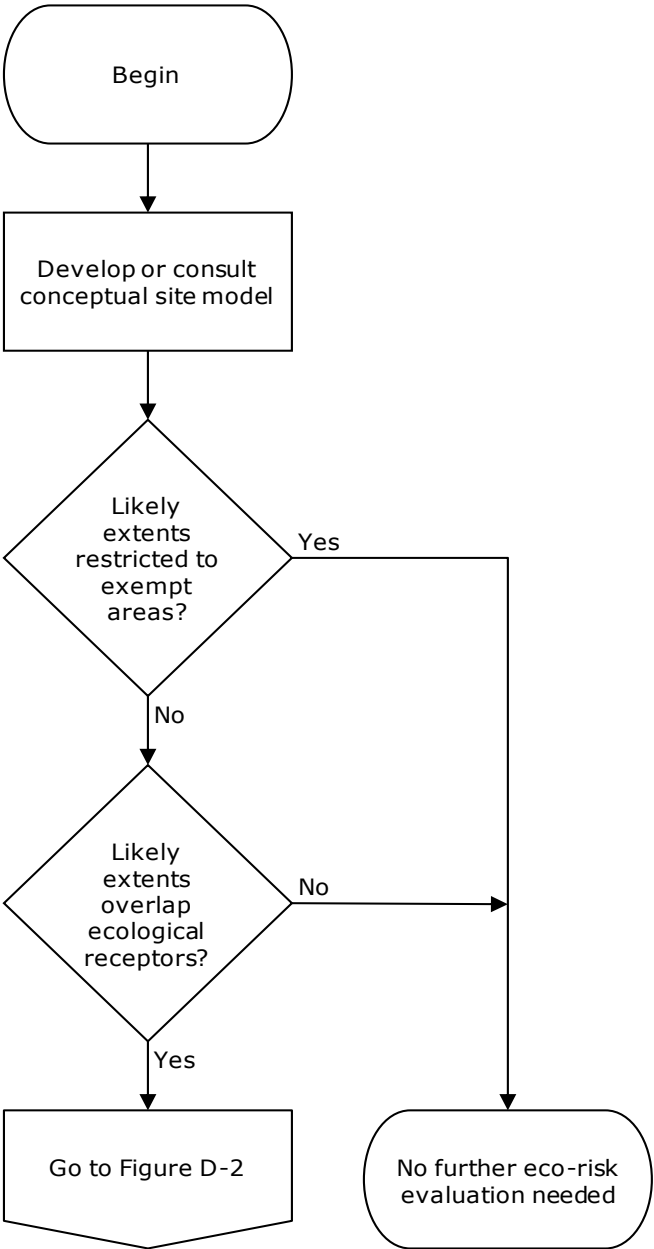
It then asks whether chemicals from the release are reasonably likely to reach an area of potential ecological significance. Examples of such areas include:

- Waters of the state, including but not limited to streams, ponds, wetlands, and associated sediment
- Parks, nature preserves, fish and wildlife areas, or legally protected areas such as conservation easements and mitigation banks
- Sinkholes or karst recharging areas
- Any other area important to the reproduction and/or survival of endangered, threatened, or sensitive species, or species of concern

Answering this question may be as simple as demonstrating that a plume of release-related chemicals in groundwater is stable and does not extend as far as the nearest potential ecological receptor (e.g., the nearest downgradient wetland). As stated earlier, information collected in conjunction with CSM development (nature, extent, and stability of release determinations, wetland inventory maps, land use information for surrounding properties, areas with endangered species, etc.) will often suffice.

If further ecological assessment is necessary, responsible parties should proceed to Section D.3.

Figure D-1: Are Release-related Chemicals Reasonably Likely to Reach Ecological Receptors?



D.3 Screening Level Ecological Risk Evaluation

This step uses sample results to derive representative concentrations of release-related chemicals found in media in one or more decision units that contain ecologically significant areas. Examples include sediment or surface water samples from a potentially impacted wetland, or surficial soil samples from an area potentially impacted by aerial deposition that is home to endangered plants. If suitable analytical data is not already available, completion of this step will require additional sampling and analysis.

This step begins with development of an ecological CSM, which may draw heavily on information already collected during development of a standard CSM. While the process diagram shown in Figure D-2 provides a basic overview of general ecological risk evaluation steps, a more detailed account is provided in U.S. EPA (2018). Important components of the ecological CSM include:

- Release-related chemicals of potential ecological concern
- Potentially affected decision units with ecologically sensitive areas
- Potentially affected media in decision units with ecologically sensitive areas

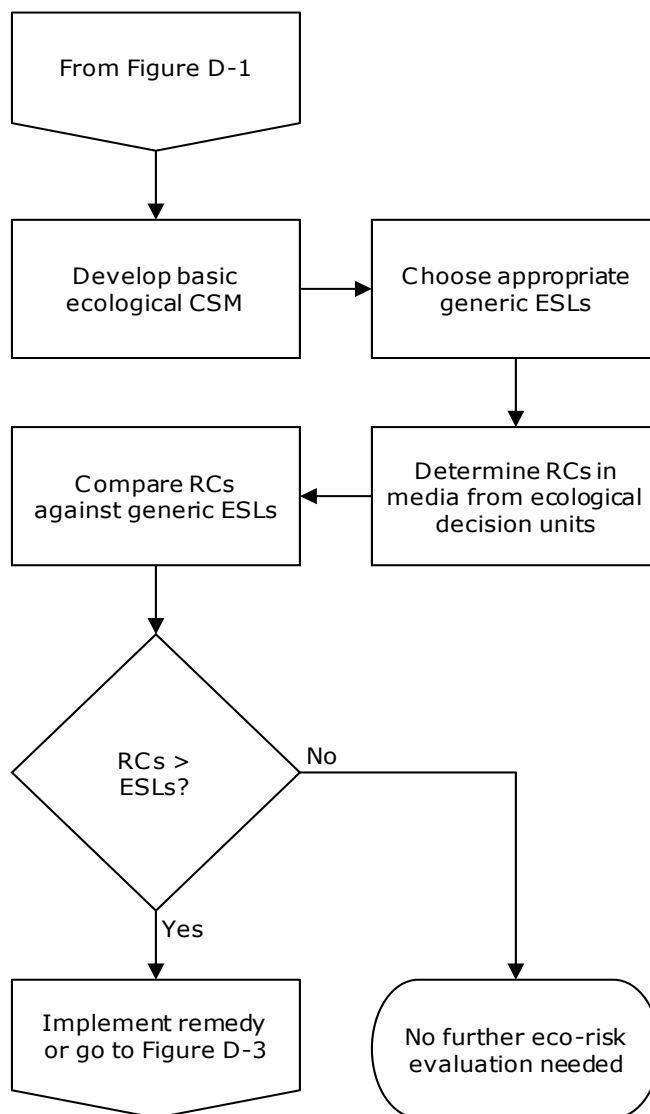
Note that chemicals that might pose an ecological risk can be different from those that might pose a human health risk. Possible reasons include differing exposure pathways, sensitivities, and responses to chemicals. Use of some generic ecological screening levels (ESLs) may also require identification of potentially affected taxa (e.g., birds, mammals, invertebrates).

Where applicable, Indiana Water Quality Standards ([327 IAC 2](#)) exist by rule and take precedence over guidance. After Indiana Water Quality Standards are considered, IDEM recommends starting with U.S. EPA Region 4 Ecological Screening Levels (U.S. EPA, 2018). Other ESL sources may be appropriate when Indiana Water Quality Standards or U.S. EPA ESLs are not available for a chemical; see especially NOAA (2008) and U.S. EPA (2006c). Following sampling and analysis of media from decision units with ecological receptors, responsible parties should calculate representative concentrations and compare those concentrations to the selected generic ESLs. Factors such as surface water hardness, temperature, and total organic carbon should be considered when collecting and using data (U.S. EPA, 2018).

Significant exceedances warrant an ecological remedy or further evaluation unless appropriate lines of evidence demonstrate otherwise. Potentially relevant lines of evidence include:

- Background concentrations
- Contributions of other sources, such as outfalls
- Existing ecological studies applicable to the decision unit
- Determination whether discharges of release-related chemicals were permitted

**Figure D-2: Do Representative Concentrations of Release-related Chemicals
Exceed Generic Ecological Screening Levels?**



Acronyms:

CSM = Conceptual site model
ESL = Ecological screening level
RC = Representative concentration

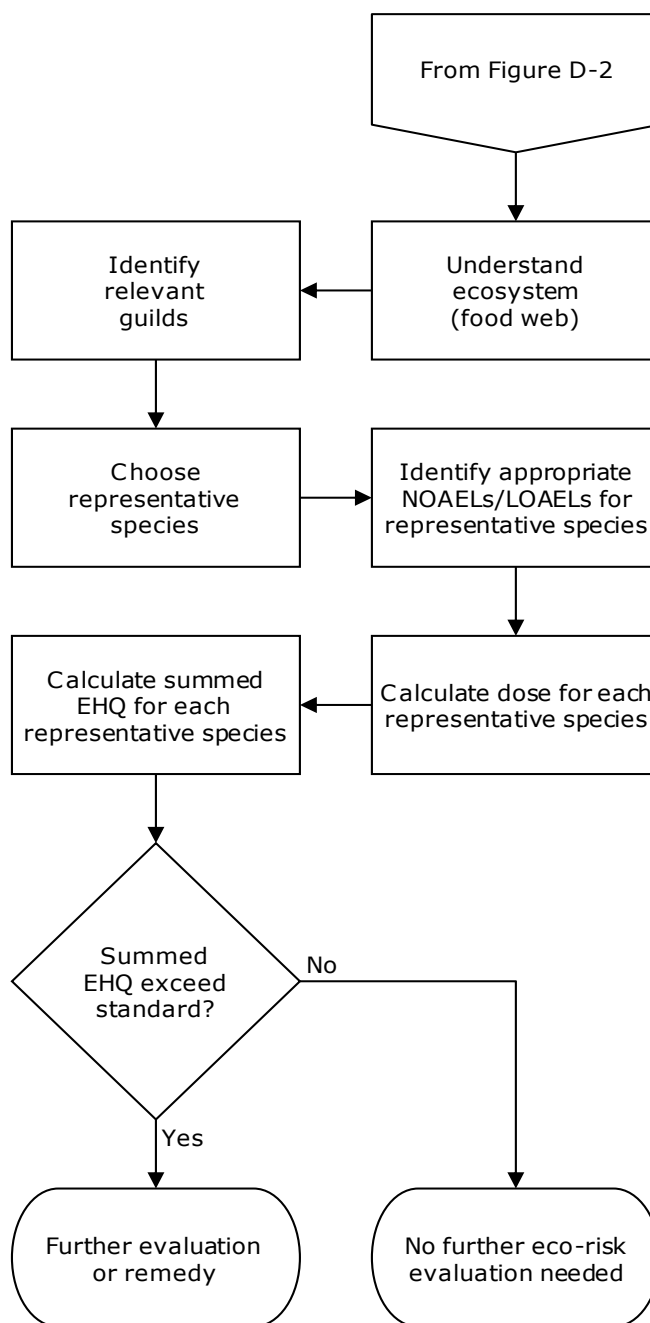
D.4 Ecological Risk Evaluation: Refinement

Whereas Section D.3 uses generic, media-specific screening levels for comparison against representative concentrations, a refined ecological risk assessment uses levels experimentally derived for species representative of various groups in the food web that are, or should be, present in the release area. An adequate ecological risk assessment may require several iterations, depending on what each step of the process reveals, and may include bioavailability studies, studies of spatial and temporal differences in feeding behavior, or other relevant lines of evidence. Figure D-3 is a decision tree that illustrates the process. Basic steps may include:

- Develop an understanding of the ecosystem (i.e., the food web) in the release area
- Identify relevant guilds (groups of organisms occupying a similar ecological niche – e.g., insectivorous birds, benthic organisms, predatory mammals, etc.)
- Choose representative species for each of those guilds (e.g., American Robin, Raccoon, Eastern Newt, etc.)
- Identify, from the literature, appropriate no observed adverse effect levels (NOAELs) or lowest observed adverse effect levels (LOAELs) for each representative species
- Calculate an estimated dose for each release-related chemical of potential ecological concern (COPEC) x representative species combination
- Compare data to Refinement Screening Values (from tables appearing in U.S. EPA, 2018)
- Calculate an ecological hazard quotient (EHQ) for each COPEC x representative species combination, where $EHQ = \text{Dose}/\text{NOAEL}$ or $EHQ = \text{Dose}/\text{LOAEL}$, and sum EHQs for different chemicals for a given representative species
- Compare EHQs to appropriate factors, discussed below
- Perform an analysis of uncertainty, and how it affects the conclusions of the assessment

If the EHQ does not exceed an appropriate factor (derived by refining ecological hazard quotients using project-specific data and exposure assumptions when generic data and assumptions result in an ecological hazard quotient exceeding one), no further ecological risk evaluation is necessary. Otherwise, additional evaluation or an ecological remedy is necessary.

Figure D-3: Do Representative Concentrations of Release-related Chemicals Exceed Project-specific Ecological Screening Levels?



Acronyms:

EHQ = Ecological hazard quotient
 LOAEL = Lowest observed adverse effect level
 NOAEL = No observed adverse effect level

D.5 How IDEM Will Evaluate Ecological Risk Evaluations

Step 1

- IDEM will decide whether it agrees with the responsible party's determination that the present and likely future extents of the release either do or do not overlap ecologically significant areas. IDEM will typically use extents maps or diagrams provided by the responsible party to make this determination, but may also choose to use aerial photographs, National Wetland Inventory maps, appropriate layers in the [IndianaMAP](#), or other resources as appropriate when making this decision. Note that extents maps and diagrams will require the concurrence of IDEM technical staff.

Step 2

- Were ecological decision units appropriately defined?
- Were appropriate ecological screening levels proposed?
- Was there sufficient sample data from each ecological decision unit?
- Were representative concentrations of each COPEC calculated appropriately?

Step 3

- In addition to factors described under Step 2, above:
- Were relevant guilds identified?
- Were appropriate representative species chosen?
- Were appropriate NOAELs/LOAELs chosen?
- Were appropriate doses calculated for each representative species?
- Were summed EHQs calculated for each representative species?
- Were appropriate ecological remediation objectives specified?
- Do summed EHQs exceed ecological remediation objectives?

Appendix E: Environmental Restrictive Covenants

An environmental restrictive covenant (ERC) is a legal measure designed to protect human health by limiting exposure to release-related chemicals. ERCs limit human exposure by restricting activity on, use of, and/or access to properties, or by requiring the operation and maintenance of an engineering control. [IC 13-25-5-8.5\(e\)](#) directs IDEM to consider and give effect to ERCs when evaluating risk-based remediation proposals.

When an ERC is proposed as a remedy or component of a remedy, IDEM will evaluate it to determine (a) whether the activities, land use restrictions, and obligations proposed are sufficient to protect human health and the environment, and (b) whether it attaches to the correct real estate (i.e. references the correct legal description, deed number, and state parcel identification number(s)) and (c) includes all the necessary elements of a restrictive covenant as defined in [IC 13-11-2-193.5](#), [IC 13-14-2-6\(5\)](#), and [IC 13-14-2-6\(6\)](#).

A proposed ERCs must be submitted to IDEM for review prior to recording. IDEM must determine whether the proposed restrictions and obligations are adequate to prevent unacceptable risk to human health to the environment, now and in the future. IDEM will also review the proposed ERC to ensure that it contains all the elements necessary to make it enforceable by IDEM. After the ERC is approved by IDEM, it must be recorded in the recorder's office in the county where the property is located.

E.1 Legal Requirements for ERCs

Per [IC 13-11-2-193.5](#), an ERC executed after June 30, 2009:

- (A) *limits the use of the land or the activities that may be performed on or at the land or requires the maintenance of any engineering control on the land designed to protect human health or the environment;*
- (B) *by its terms is intended to run with the land and be binding on successors;*
- (C) *is recorded with the county recorder's office in the county in which the land is located;*
- (D) *explains how it can be modified or terminated;*
- (E) *grants the department access to the land;*
- (F) *requires notice to a transferee of:*
 - (i) *the land; or*
 - (ii) *an interest in the land;*
 - of the existence of the restrictive covenant; and*
- (G) *identifies the means by which the environmental files at the department that apply to the land can be located.*

Per [IC 13-14-2-6\(5\)](#), and [IC 13-14-2-6\(6\)](#), the terms of an ERC may be enforced by IDEM in court if the ERC:

Was approved by IDEM and created in connection with any

- (i) *remediation;*
- (ii) *closure;*
- (iii) *cleanup;*
- (iv) *corrective action; or*
- (v) *determination exercising enforcement discretion or of no further action being required.*

IDEM's [Institutional Controls webpage](#) provides program specific ERC templates that both fulfill the legal definition of an ERC and have been vetted by IDEM's Office of Legal Counsel. The provided templates are fill-in-the-blank Word® documents. Should the property owner decide to modify the provided language in these templates, IDEM's Office of Legal Counsel must review those modifications to ensure

that the revised ERC satisfies the legal definition of an ERC. This legal review will require additional time and should be taken into consideration for the project's timeline.

E.2 Selection of Land Use Restrictions and Obligations

When determining the appropriate restriction or obligation required for a property, consider the following:

- Affected media
- Current and reasonably expected future groundwater use
- Current and reasonably expected future use of each decision unit and neighboring properties
- Properties of the release-related chemicals (e.g., mobility, naturally attenuating, etc.)
- Current and potential receptors
- Availability of public water supply systems

Table E-1 lists some factors to consider when selecting appropriate land use restrictions for a property. Table E-1 is not comprehensive - other restrictions may be necessary. In accordance with [IC 13-14-2-8](#), IDEM shall make the final determination on the land use restrictions that are protective of human health.

Table E-1: Restrictions and Remedies

Medium	Remediation Objective Exceeded	Possible Land Use Restrictions
Soil	Unconditional	<ul style="list-style-type: none"> • Residential restriction; or • Soil cap with OMM plan • Proper soil handling & disposal • Agricultural restriction⁴³
	IDEM Published Commercial Level, or equivalent	<ul style="list-style-type: none"> • Residential restriction • Soil cap with OMM plan • Proper soil handling & disposal • Soil management plan
	IDEM Published Excavation Worker, or equivalent	<ul style="list-style-type: none"> • Excavation restriction • Soil cap with OMM plan • Proper soil handling & disposal • Soil management plan
Groundwater	Unconditional	<ul style="list-style-type: none"> • Groundwater use restriction • Agricultural restriction⁴⁴
Vapor	Unconditional	<ul style="list-style-type: none"> • Residential restriction • Test before residential use • Vapor mitigation system with OMM plan • Vapor barrier • Basement restriction⁴⁵
	IDEM Published Commercial Level, or equivalent	<ul style="list-style-type: none"> • Test before residential use • Vapor mitigation system with OMM plan • Vapor barrier • Basement restriction (if groundwater is shallower than eight feet below ground surface)

⁴³ Generally, an agricultural restriction is considered when impacts and groundwater are shallow, release-related chemicals are bioaccumulative (e.g., PCBs or metals) and/or an engineered cap is in place.

⁴⁴ For groundwater shallower than five feet below ground surface

⁴⁵ If groundwater acting as a vapor source did not previously prompt a vapor investigation based on the current structure configuration but the addition of a basement would prompt a vapor investigation, a future use basement restriction may be acceptable to prevent exposure.

E.3 Property Description

ERCs must be recorded in the county recorder's office in which the real property is located, and the ERC must cross-reference the most recent deed of the record in the recorder's office. To ensure that the ERC is attached to the correct property, provide a copy of the current deed along with the draft ERC to IDEM. IDEM's GIS Services will plot the legal description to create a geographic information system (GIS) polygon of the restricted property. The ERC should also include the correct address, 18-digit State Parcel Identification Number (PIN), and legal description provided on the current deed. An ERC is recorded on the property deed. If an ERC is proposed as a remedy, the ERC must be agreed to and executed by each person owning an interest in the property. If one deed contains descriptions of several parcels, or several deeds are included in a single ERC, it should be made clear which obligations and restrictions are applicable to each parcel, and/or which parcels are not involved at all.

E.4 Affected Area

An **affected area** is a portion of real property impacted by concentrations of release-related chemicals that requires a remedy that may not be necessary for the rest of the property. The driver for the restriction, or the obligation, may be either the specific chemical or the media in which it is found. When an affected area is involved, it is crucial to accurately delineate the boundaries of the affected area based on data for each impact and to accurately depict it on a map. This may be accomplished using GPS points to clearly delineate the boundaries or by conducting a survey of the area.

Define affected area boundaries using sampling data for the chemicals and media involved. Affected areas may differ by media. For example, soil sampling data immediately surrounding a drum storage pad may define an affected area for soil that requires restrictions or obligations specific to controlling risk from exposure to that soil. However, if the same release has created a much larger affected area in groundwater, that larger area will require restrictions or obligations specific to controlling risk from exposure to that groundwater. The overall affected area must encompass all chemical-specific and media-specific affected areas related to the release.

In other instances, off-site properties may be affected and require a remedy. If the approved remedy on such property is an ERC, it is the responsibility of the entity proposing the remedy to obtain the executed document and see that it is recorded.

E.5 Finalized ERCs

Once a draft ERC has been reviewed by IDEM and finalized, it must be signed and notarized by the current property owner. If there is more than one person who owns the property, each person must sign the ERC. Either the property owner, or an authorized representative⁴⁶ of the property owner, can record the ERC on the property deed in the recorder's office in the county where the property is located. Provide a copy of the recorded ERC to IDEM. IDEM provides a copy of the recorded ERC to the county health department and/or county well permitting authority in which the property is located. IDEM will visually depict the property location on IDEM's GIS map as well as IndianaMap to ensure that future property owners and neighboring properties' owners are aware of release-related chemicals remaining on the affected properties in their communities.

ERCs are typically recorded at the end of the remedy implementation process as part of a closure. However, there are instances (e.g., when the property is going to be transferred, when full implementation of a remedy may take a long time, or when the property may be eligible for a tax sale) in

⁴⁶ An authorized representative is someone who has power of attorney for the property owner, or has authority to sign on behalf of an entity such as a municipality, corporation, or LLC.

which it may be appropriate to record an ERC prior to the end of the remedial process. Modification of a previously recorded ERC may be required if the restrictions and obligations are no longer adequate to protect human health and the environment. Any such modification must be approved and recorded before IDEM will approve closure.

IDEM has the authority to require the owner of the source property to place necessary restrictions on that property. In some limited circumstances, property owners meeting the criteria in [IC 13-25-4-24](#) may be required to execute an ERC if the commissioner determines an ERC is necessary to protect human health or the environment. If the owner refuses to execute an ERC voluntarily, IDEM may file an action in court requesting an order from the court requiring an ERC be executed.

E.6 ERC Modification or Termination and Cost Recovery

The law provides a procedure under [IC 13-14-2-9](#), and regulations promulgated thereunder, for making changes to the restrictions and obligations or for terminating the restrictions in an ERC. An owner desiring approval to change the use of a property, to modify a restriction or obligation due to a transaction, or to terminate a restriction entirely can submit a proposal to IDEM indicating the modification desired along with the supporting data and information necessary to justify the modification or termination.

Unless an ERC is modified or terminated, it applies to a property in perpetuity. Submittals requesting to modify or terminate restrictions or obligations may be submitted to IDEM with sufficient data to support a determination that a modification or termination is justified. IDEM will approve the proposed change or termination, or it will deny the request. Any modification or termination of an IDEM-approved ERC also requires IDEM approval.

OLQ requires reimbursement for the administrative and personnel expenses associated with the development of the written determination under [329 IAC 1-2-7](#). IDEM will bill OLQ personnel expenses at \$75.00 per hour (subject to change) for the review. Once the review is completed, IDEM will issue an invoice reflecting the actual number of hours spent on the review. OLQ will not issue the written determination until payment for invoiced costs is received.

Individuals who propose modification or termination of an ERC must provide written justification and all supporting documentation necessary for review, including the following completed forms.

- ERC/Deed Notice Modification or Termination Request - 56082 (available on the [IDEM Forms](#) page), and either
- [ERC Modification Template](#) or [ERC Termination Template](#)

If IDEM concurs, a modification or termination document stating the reasons for the change, and IDEM's approval of the change, will need to be recorded in the same manner as the original ERC. A copy of the recorded modification or termination must be provided to IDEM.

E.7 Institutional Controls Registries

IDEM staff will enter information from recorded ICs into an Institutional Control Registry. IDEM maintains two registries; a Remediation Sites registry that is a listing of properties with recorded ERCs, and a Solid Waste Registry that is a listing of solid waste landfills with recorded deed notices or ERCs. The registries allow IDEM to track properties with ICs and provide external stakeholders (local government units, water utilities, real estate developers, concerned citizens, etc.) notice of properties subject to restricted use or obligations.

IDEM updates the [IC Registries](#) every month. The reports contain project-specific information on each property with an institutional control, such as the address, city, county, remediation program, and a listing of land use restrictions and/or engineered controls. There are two active links on the registries. The first

active link is to IDEM's Virtual File Cabinet to provide direct access to the institutional control document. The second active link is to a GIS map that depicts the restricted properties and provides information on those properties.

E.8 How IDEM Will Evaluate Environmental Restrictive Covenants

IDEM will consider the following when reviewing environmental restrictive covenants:

ERC Format

- Was a program-specific ERC template used?
- If a program-specific template was used, has the standard language been significantly modified?
- IDEM does not require use of a program-specific template. However, if a template is not used, the proposed ERC will require additional scrutiny, including by IDEM's Office of Legal Counsel. This will result in a longer review time for the proposed ERC.

ERC Recitals

- Is the name and full address of the owner listed, correct, and used throughout?
- If the deed is in the name of a different person or entity than the person who is signing the ERC, are there recitals to connect the two parties? (e.g., the names are different because of death/inheritance, corporate mergers, or bankruptcy).
- Is the full address of the property listed and correct?
- Have the correct parcel identification numbers been provided?
- Is the total acreage correct?
- If provided, is the summary of remedial activities accurate?
- If provided, are the factual statements made in the recitals correct?

ERC Restrictions

- Are the restrictions appropriate based on the remaining chemicals and concentrations?
- Are any groundwater restrictions property-wide, unless an acceptable explanation is provided to justify restricting groundwater usage to only a portion of the property?
- Are any of the restrictions to be applied only in an "affected area" instead of the entire property?
- If restrictions are applied to an "affected area", is it clearly described in the text and depicted on an attached map?
- If any of the restrictions are to be applied only to an affected area or if an engineering control such as a cap or cover is present, have GPS coordinates or a legal survey of the affected area been provided?
- If a program-specific template was used, has any of the default restriction language contained in the template ERC been modified? If so, is the language acceptable?

ERC Exhibits

- Was a copy of the warranty deed provided?
- Does the owner name listed in the ERC match the owner shown on the deed?
- Is the legal description from the warranty deed included as an exhibit to the ERC?
- If a map was provided, is it legible?
- If a restriction or obligation covers only a portion of the property, is a map of that portion provided?
- Does the ERC and its narrative, in conjunction with the map, contain information that would enable an inspector, unfamiliar with the property, to determine the location of the affected or restricted area?

- If one or more tables are included, have they been edited to remove sample points where concentrations of release-related chemicals are non-detect or below unconditional remediation objectives?
- Is the font size used in the exhibits at least 10 point?
- Are the exhibits without color, hatching, or shading so that they can be scanned in black and white?
- Do the exhibits in the ERC match the title pages?

Appendix F: Environmental Restrictive Ordinances

[IC 13-11-2-71.2](#) defines an environmental restrictive ordinance (ERO) as an ordinance adopted by a municipal corporation⁴⁷ that seeks to control the use of groundwater in a manner and to a degree that protects human health and the environment against unacceptable exposure to a release of hazardous substances or petroleum, or both.

Per [IC 13-25-5-8.5\(e\)](#), IDEM must consider and give effect to EROs in evaluating risk-based remediation proposals. IDEM will not consider an ERO as a remedy for a source property under the control of a current owner. Because EROs are defined to eliminate access to groundwater, vapor intrusion issues, if those conditions exist, must be addressed through a different remedy.

Because IDEM has the responsibility to ensure that remedies protect human health, it will review EROs for effectiveness. Effective EROs *prohibit* use of groundwater that exceeds unconditional remediation objectives for potable use and, depending on the release-related chemical(s), remaining concentrations, and plume dynamics, *may* prohibit use of groundwater for other purposes (e.g., irrigation, cooling water, etc.). EROs may not be acceptable where plumes encroach on, or fall within, a wellhead protection area (WHPA).⁴⁸ ERO effectiveness depends in part on understanding the present and future extents of release-related chemicals in groundwater and ensuring that the ERO area fully encompasses those extents and a recommended additional buffer zone area. The CSM will inform design of the ERO area, and the design may also employ lines of evidence from a plume behavior evaluation.

EROs that allow for special use exceptions or variances may unintentionally permit future unacceptable exposure to release-related chemicals in groundwater. Therefore, before granting a variance or exception, local government units should ensure that the proposed changes will not result in unacceptable exposure.

Depending on release-specific factors (unusually toxic or persistent chemicals, large and/or unstable plumes, etc.) IDEM may condition its approval of a remedy that relies on an ERO on the responsible person's compliance with continuing obligations. For example, IDEM may condition closure approval on the responsible person's continued groundwater monitoring to ensure that the plume does not extend beyond the established boundaries of the ERO. In addition, the responsible person may need to take other remedial measures to control exposure via pathways (such as vapor intrusion) not addressed by the ERO.

F.1 ERO Notification Provisions

In accordance with [IC 36-1-6-11\(c\)](#), EROs enacted after 2009 must provide notice to IDEM under certain situations. Failure to include such language regarding notice in the ordinance *does not*, however, void the ordinance. Such an ordinance may also require that the entity requesting the use of the ordinance propose additional measures to ensure that notice is provided to IDEM. Notice to IDEM is required as follows:

- Giving written notice to IDEM not later than 60 days *before* amendment or repeal of the ERO

⁴⁷ As defined in [IC 36-1-2-10](#). For purposes of this guidance, a municipal corporation may include counties, municipalities, townships, local hospital corporations, or any entity that may enact an ordinance.

⁴⁸ Either the five-year time of travel of a delineated WHPA or a 3,000-foot fixed radius WHPA for a community water system. In accordance with [IC 5-14-3-4\(b\)\(19\)\(H\)](#), locations of approved WHPAs are not available online. For general information regarding WHPAs consult the [IDEM Wellhead Protection Program](#); to determine whether a specific release is within a WHPA, contact IDEM's Ground Water Section via phone at 317-232-8603.

- Giving written notice to IDEM not later than 30 days *after* passage, amendment, or repeal of an ERO

Local government units should send these notices to IDEM at the following address:

IDEM, Office of Land Quality
Remediation Services Branch
Attn: Institutional Controls Group
IGCN-Suite 1101
100 N Senate Ave
Indianapolis, IN 46204-2251

F.2 How IDEM Will Evaluate Environmental Restrictive Ordinances

IDEM will thoroughly evaluate EROs proposed as a component of a remedy. Approval of an ERO for one release does not ensure that other releases within the boundaries of the ERO will automatically be granted closure based on that same ERO. Use of an ERO as a proposed remedy will be evaluated on a case-by-case basis and evaluated according to the facts applicable to each release. ERO evaluations will include at a minimum:

1. An assessment of plume extents and stability of the plume. There should be sufficient understanding of the plume mass flux to demonstrate that the plume will not migrate beyond the boundaries established in the ERO at levels that would not be considered protective of human health. This may be accomplished by:
 - a. Identifying characteristics of the release setting and the plume that provide a level of confidence that the plume is near its maximum extent and concentration.
 - b. Demonstrating that the plume is stable or shrinking, prior to acceptance of an ERO as an IC for a particular release; or
 - c. Long-term monitoring that demonstrates that the plume does not extend beyond the boundaries established in the ERO.
2. Location of the release with respect to the ERO coverage area. The ERO coverage area should include the plume, predicted future plume extents, and usually should include a buffer zone.
3. Evaluation of the receptor survey. The receptor survey should thoroughly document all water use within and near the ERO boundaries including:
 - a. Potable well users within ERO extent (noting that some commercial wells are also used for potable water).
 - b. Commercial, dewatering, and irrigation wells.
 - c. Nearby water withdrawals (such as high-capacity wells near the ERO coverage area that may impact the plume).
 - d. Food or drug manufacturing facilities that use groundwater wells.
4. Input from the local government unit that has enacted or that has proposed adoption of the ERO. Responsible parties and their consultants are encouraged to work directly with the local government unit. Because IDEM must rely on local governments to enforce EROs, municipal involvement throughout the review process will help IDEM evaluate the effectiveness of proposed EROs. The responsible party will contact local governments for information including:
 - a. Current and future local water resource planning.

- b. Procedures for granting exceptions and variances to the ERO.
- c. Local point of contact for ERO monitoring and compliance.
- d. Notification provisions for EROs.

IDEM will notify local government units, including public water supply systems, in writing of any formal proposal to use an ERO at a particular location; and will request input on the items listed above if the information has not already been provided in the work plan.

5. Future effectiveness of the ERO (notice to interested parties). IDEM has the responsibility to ensure that remedial decisions are protective of human health. One of the documented limitations with the use of local groundwater ordinances as an IC is that their continued effectiveness hinges on public acceptance and awareness of the ordinance. In Indiana, this is particularly important given the lack of comprehensive state-wide well permitting requirements. Continued compliance with an ERO is necessary for the ERO to remain effective at managing risk and controlling unacceptable exposure. Therefore, a plan or mechanism that ensures continuing public awareness of, and compliance with, the ERO can help to ensure that the ERO remains effective at managing risk. Some examples of such plans may include but are not limited to:
 - a. If there is an existing local well permitting authority, notification to that entity of the existence of the ERO so that no potable wells, or wells that may exacerbate the risk, are permitted.
 - b. Active monitoring and outreach by the local government unit so there is an ongoing public awareness of the ERO.
6. Evaluation of the ERO language. IDEM will evaluate each ERO on its own merits, and there is no requirement to follow a template. However, clear, unambiguous ERO language is recommended, such as:
 - a. A statement indicating that the purpose of the ERO is to protect public health, and that the ordinance has been enacted as a response to unacceptable groundwater risk.
 - b. Language that specifically excludes all use of groundwater as a potable drinking water source for human and domestic purposes and prohibits the installation of new wells. An ordinance that just requires hookup to an existing water supply only if supply lines are available, or one that allows existing wells to remain in use, may not be sufficiently protective of human health.
 - c. A clause that states that the ERO shall not in any way restrict or limit the ability of parties to perform remediation or to monitor the release.
 - d. Language that limits the variances or exceptions allowed by the ERO⁴⁹, and requires the proper handling and disposal of water that is withdrawn.
 - e. If the ERO does not apply everywhere within the boundaries of the local government unit, the extent of the ERO should be easily identifiable and clearly defined within the ERO (e.g., map or illustration showing ERO boundaries, legal description of ordinance boundaries, or common reference points such as street names). A buffer zone outside of the modeled/measured plume area is recommended to compensate for the potential influence on the plume by nearby water withdrawals. ERO boundaries should be fixed and should not be subject to change without

⁴⁹ Examples include irrigation wells, heat pump wells, cooling water wells, fire protection wells, construction dewatering wells.

amending the ERO (e.g., no boundaries defined by zoning districts or the availability of public water).

- f. Language that specifies that the ERO applies at all depths and is not limited to specific aquifers.

Final acceptance by IDEM will depend on ERO content, effectiveness, and adoption by the local unit of government. IDEM will not issue closure documentation prior to receiving certification from an authorized official that the approved ERO meets the requirements of the governing statute and has been lawfully adopted by the local unit of government.⁵⁰ IDEM will draft closure documents so that closure decisions may be revisited if IDEM receives or becomes aware of new information. Examples of circumstances where this is likely to happen include: 1) the ERO is subsequently amended in a manner that allows plume movement beyond the established ERO control area or would allow exposure to release-related chemicals in groundwater, 2) the ERO is repealed, 3) variances/exceptions are granted that could allow for exposure to groundwater that exceeds unconditional remediation objectives, or 4) there is evidence that exposure to groundwater that exceeds unconditional remediation objectives is occurring within an ERO approved as an IC. IDEM will enter all EROs used as a component of a remedy in IDEM's Institutional Controls Registry.

⁵⁰ The ERO copy should be certified [signed by the local authority and attested by the town clerk-treasurer ([IC 36-5-2-10.2](#)) or city clerk ([IC 36-4-6-17](#)).]

Appendix G: Financial Assurance

Certain conditional closures may include the incurrence of continuing expenses. Examples include remedies with ongoing operational, maintenance, and/or sampling costs, or remedies that require periodic replacement of limited-life components. Financial assurance (FA) is a guarantee that funds will be available for such expenses if the responsible party becomes insolvent. In this context, the term responsible party refers to the property owner, operator, or program participant who is providing the financial assurance. When there is a substantial potential exposure risk from failure or need for eventual replacement of a costly remedy, IDEM may request that responsible parties establish and maintain FA to operate and maintain the remedy as a condition of closure.

When FA is considered necessary, it will be established under an agreement such as an Agreed Order, Voluntary Remediation Agreement, or Long Term Stewardship Agreement. This guidance does not address specific rules and regulations related to financial assurance required as part of a Resource Conservation and Recovery Act (RCRA) treatment, storage, and disposal facility permit for operation or corrective action under [329 IAC 3.1](#) or 40 CFR Parts [260-268](#) and [270](#); or financial assurance required as part of a solid waste permit or registration required under [329 IAC 10](#) (relating to solid waste disposal facilities); [329 IAC 11](#) (relating to solid waste processing facilities); [329 IAC 11.5](#), [329 IAC 11.6](#), or [329 IAC 11.7](#) (relating to biomass anaerobic digestion facilities and biomass gasification facilities, mobile home salvaging facilities, and alternative fuel source facilities, respectively); [329 IAC 15](#) (relating to waste tire management facilities); and [329 IAC 16](#) (relating to electronics waste management facilities). For the specific financial assurance requirements relating to these types of facilities, see these rules and regulations.

G.1 Financial Assurance: Determining Amount

The FA amount requested of the responsible party will be no less than the cost estimate to operate, maintain, and inspect engineered controls (ECs) for which FA is required for the duration of the risk. If the duration of the risk is expected to last for an extended time, FA will need to be structured for an appropriate rolling time period.

Cost estimates to operate and maintain the remedy are based on the costs to the responsible party of hiring a third party to conduct the necessary activities. Generally, the cost estimate is calculated by multiplying the annual cost estimate by the number of years necessary to operate and maintain the remedy. In cases where a remedy will require the eventual replacement of an engineered system or control, the cost estimate includes the cost of such replacement.

When a remedy involves FA, the closure mechanism will obligate the responsible party to review and update cost estimates at least once every five years, or more often if necessary to reflect changing circumstances, either by completing a new cost estimate in current dollars, or by multiplying the previous year's cost estimate by a specified inflation factor. The financial instruments will then need to be updated to cover the new cost estimates, and both the cost estimate and adjusted instruments submitted to IDEM.

Some costs, such as erosion control and groundwater sampling, might be reduced over time as the cover vegetation matures and a meaningful amount of monitoring data is accumulated. Due to project-specific conditions, a shorter or longer remedy operation and maintenance period might be determined to be appropriate; however, FA will need to be maintained until the threat of harmful exposure is demonstrated to no longer exist.

When evaluating the amount of FA needed to ensure the effectiveness of the remedy, IDEM will apply the following guidelines:

- Activities are described in an operation and maintenance plan in sufficient detail to facilitate review of the cost estimates
- Cost estimates are itemized in detail
- Cost estimates reflect the costs to hire a third party to conduct the remedy operation and maintenance activities

G.2 Financial Assurance: Timeframe for Establishing

After the nature and extent of release-related chemicals have been adequately determined, any interim remedial activities have been completed, and a long-term remediation and/or exposure control method has been approved by IDEM, the responsible party should then proceed to obtain FA via one of the mechanisms listed below. IDEM will not issue a closure certification, covenant not to sue, or other closure documentation until after review and acceptance of the financial mechanism by IDEM staff. When closure is based on the provision and maintenance of FA and a responsible party fails to maintain adequate FA, the conditions for closure will no longer be met and IDEM may require the responsible party to take further action.

G.3 Financial Assurance: Instruments

The following five types of financial instruments are allowed under current RCRA rules. IDEM may, at its discretion, consider alternatives to these instruments. The responsible party may propose to use any of these instruments, and IDEM will evaluate the appropriateness of the requests. Each instrument is briefly described below.

1. **Trust Fund.** A trust fund is an agreement between two parties wherein the responsible party (Grantor) sets aside a specific amount of cash or funds, which is held in trust by a second party (the Trustee) for the purpose of paying for operation and maintenance of the remedy. IDEM is named as the beneficiary of the trust. In the event of bankruptcy, IDEM uses the funds in the trust to hire a third-party contractor to operate and maintain the remedy.
2. **Letter of Credit (LOC).** An irrevocable standby LOC is a document issued by a bank or other financial institution that guarantees the payment of a responsible party's obligation for up to a stated dollar amount for a specified time. The responsible party arranges with a financial institution to issue an LOC payable to IDEM, assuring that the responsible party will pay for operation and maintenance costs when necessary. Essentially, an LOC substitutes the bank's credit for that of the responsible party, eliminating the financial risk to the state. An LOC is always accompanied by a stand-by trust agreement, which creates a trust into which IDEM will deposit the funds from the LOC in the event that it must cash in the LOC in order to continue operation and maintenance of the remedy should the responsible party be unable to do so.
3. **Surety Bond.** Like an LOC, a surety bond is an agreement between two parties. One party (the Surety) guarantees that the financial obligations of the second party (the Principal) will be met. For purposes of FA, the responsible party is the Principal. By means of the bond, the Surety guarantees to IDEM that it will meet the responsible party's obligations if the responsible party is unable to do so. A surety bond is always accompanied by a stand-by trust agreement, which creates a trust into which IDEM will deposit the face value of the surety bond in the event that the responsible party has failed to meet its obligations under the terms of the bond.
4. **Insurance.** A responsible party may obtain an insurance policy for a face value amount at least equal to the cost estimate for the operation and maintenance of the remedy. Through a policy, the insurer agrees to reimburse the party that incurred the cost of the operation and maintenance upon direction from IDEM, for costs incurred to operate and maintain the remedy. The insurer must be licensed by a state (use of offshore insurers is not allowed) and may not cancel, terminate, or fail to renew the policy unless the responsible party fails to pay the premiums.

Should the insured fail to renew the policy or pay the policy premiums, an alternative form of financial assurance will be required.

5. Financial Test. A responsible party may demonstrate the ability to cover the costs of operation and maintenance of the remedy without a third-party guarantee by passing a financial test. With this form of FA, the company is responsible for paying costs associated with operation and maintenance of the remedy. These tests document that the responsible party has sufficient assets located within the United States to cover operation and maintenance costs. Only companies with large net worth relative to the total estimated costs of remedy operation and maintenance are likely to pass a financial test. The responsible party demonstrates that they continue to pass the financial test by submitting updated information to IDEM within 90 days after the close of each fiscal year.

A responsible party may obtain a Corporate Guarantee from a separate but related company to cover remedy operation and maintenance costs in the event the responsible party is unable to meet the Financial Test. The related company demonstrates the ability to serve as a guarantor for the responsible party by passing the financial test.

G.4 How IDEM Will Evaluate Financial Assurance

A draft version of the FA instrument must be submitted for review and evaluation. The FA instrument must be funded to the approved cost estimate and must use IDEM's non-negotiable language for Financial Assurance Instruments. IDEM staff will review and either comment on or approve the FA instrument. Once approved, the FA instrument must be implemented and submitted to IDEM. FA is required to be updated annually.

Acronyms, Initialisms, and Abbreviations

µg	microgram
AF	adherence factor
ALM	Adult Lead Model
ASTM	American Society for Testing and Materials (formerly; now ASTM International)
BGS	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylene
BTV	background threshold value
BW	body weight
CASRN	Chemical Abstracts Service Registry Number
CFR	Code of Federal Regulations
cm	centimeter
COPEC	chemical of potential ecological concern
Csat	soil saturation limit
CSM	conceptual site model
cVOC	chlorinated volatile organic chemical
DNAPL	dense nonaqueous phase liquid
DQO	data quality objective
DQOP	Data Quality Objectives Process
DU	decision unit

EC	engineering control
ED	exposure duration
EF	exposure frequency
EHQ	ecological hazard quotient
EPA	(U.S.) Environmental Protection Agency
ERC	environmental restrictive covenant
ERO	environmental restrictive ordinance
ESL	ecological screening level
ET	exposure time
FA	financial assurance
FID	flame ionization detector
GC	gas chromatography
GC/MS	gas chromatography/mass spectroscopy
GIS	geographic information system
GW	groundwater
hr	hour
HVAC	heating, ventilation, and air conditioning
IAC	Indiana Administrative Code
IBP	Indiana Brownfields Program

IC	Indiana Code <i>or</i> institutional control
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
IDW	investigation derived waste
IEUBK	integrated exposure uptake biokinetic (model)
IRIS	Integrated Risk Information System
IRS	intake rate
ITRC	Interstate Technology and Regulatory Council
kg	kilogram
l	liter
LC/MS	liquid chromatography/mass spectroscopy
LNAPL	light nonaqueous phase liquid
LOAEL	lowest observed adverse effect level
LOC	letter of credit
LTS	long term stewardship
m	meter
MCL	maximum contaminant level
MDDR	minimum data documentation recommendation
µg	microgram

mg	milligram
mg/kg	milligrams per kilogram
MS	matrix spike
NAPL	nonaqueous phase liquid
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanographic and Atmospheric Administration
NOAEL	no observed adverse effect level
NPD	nonrule policy document
NPDES	National Pollution Discharge Elimination System
NYDoH	New York Department of Health
OLQ	Office of Land Quality
OMM	Operation, maintenance, and monitoring
OSHA	Occupational Safety and Health Administration
PAH	polyaromatic hydrocarbon
PCB	polychlorinated biphenyl
PID	photoionization detector
PIN	parcel identification number
POC	perimeter of compliance
ppb	parts per billion
PVI	petroleum vapor intrusion

QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
R2	<i>Risk-based Closure Guide</i>
RC	representative concentration
RCG	<i>Remediation Closure Guide</i>
RCRA	Resource Conservation and Recovery Act
RMSD	root mean squared deviation
RO	remediation objective
RP	responsible party
RRC	release-related chemical
RSL	regional screening level
SA	skin surface area
SAP	sampling and analysis plan
SCP	State Cleanup Program
SGe	soil gas, exterior
SGss	soil gas, subslab
SPLP	synthetic precipitation leaching procedure
SSDS	subslab depressurization system
TSD	treatment storage and disposal
UCL	upper confidence limit of the mean

URO	unconditional remediation objective
USDA	United States Department of Agriculture
U.S. EPA	United States Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic chemical
VRP	Voluntary Remediation Program
WHPA	wellhead protection area
yr	year

Glossary

Active remedy	A deliberate measure intended to reduce release-related chemical concentrations in a decision unit.
Adequate remedy	A measure that either by itself or in concert with one or more other measures reduces risk from release-related chemicals to an acceptable level for the intended use of a decision unit.
Aquifer	An underground geological formation as defined in IC 14-25-7-1 .
Buffer zone	A defined area surrounding the current and likely future extents of a plume of release-related chemicals in groundwater. Buffer zones are intended to protect potential receptors outside the current and likely future extents of the plume. Buffer zone boundaries will vary depending on the chemicals, their concentrations, and other location-specific conditions. Buffer zone dimension determinations will require concurrence from IDEM project management and science staff, and should protect human health in perpetuity.
Characterization	A determination of the source, nature, and extents of release-related chemicals.
Closure	IDEM's written recognition that a party has demonstrated attainment of remediation objectives for a release.
Commercial indoor air action level	For a given chemical, ten times the IDEM published level for commercial indoor air, which corresponds to a carcinogenic risk of 10^{-4} or a hazard quotient of ten, whichever results in a lower concentration.
Conceptual site model	A comprehensive understanding of the release, including its setting, characterization, an evaluation of risks associated with the release, and remedy/ies proposed and implemented to address those risks.
Conditional closure	A closure that requires an ongoing remedy.
Conditional remediation objective	A remediation objective that does not permit unrestricted use of a decision unit. For example, IDEM's published levels for commercial soil are conditional remediation objectives because they are calculated assuming no residential use.
Decision unit	A geographic location where exposure to release-related chemicals may occur, that requires a decision about whether a remedy for that exposure at that location is necessary.
Deep soil gas	Soil gas from more than five feet below ground surface.
Delineation	The act of determining the extents of a release.
Engineered exposure control	A physical structure or apparatus that reduces or controls exposure.
Exempt area	An area that is <i>not</i> subject to ecological risk evaluation.

Extents	The volume or two-dimensional projection in horizontal space of a volume of media that contains release-related chemicals at concentrations or risk levels that exceed unconditional remediation objectives.
Line of evidence	A fact or set of facts relevant to a decision.
Naturally occurring background	Substances present in the environment at concentrations that have not been influenced by human activity (e.g., arsenic in New Albany shale).
Nature	The identity and concentrations of release-related chemicals in various media.
Off-site source	A separate, identifiable, localized source from outside the original location of interest that contributed release-related chemicals to the site (e.g., chlorinated solvents from a dry cleaner impacting a neighboring business that has no history of using those solvents).
Plume behavior	How release-related chemical concentrations change spatially and over time, and interact with potential receptors.
Published level	A concentration published by IDEM for a chemical in a particular medium which is acceptable for a specified exposure scenario.
Release	IC 13-11-2-184 provides various definitions of <i>release</i> that apply to different remediation programs.
Release-related chemical	A substance placed on the land or in the subsurface that is, by virtue of its nature or quantity, subject to regulation by IDEM's Office of Land Quality. The term also includes regulated breakdown products of the above.
Remediation objective	Per IC 13-25-5-8.5(b) , either (1) a concentration of a substance equal to the naturally occurring concentration of that substance on the site, or (2) an environmental concentration of a substance that is, given the conditions, uses, and restrictions prevailing on the site, protective of human health and the environment. For purposes of this document, a remediation objective may be a conditional remediation objective or an unconditional remediation objective.
Remedy	A means of reducing risk arising from a release-related chemical. Remedies either reduce the concentration of a release-related chemical, reduce exposure to that chemical, or both. An adequate remedy will, either by itself or in concert with one or more other remedies, reduce risk from release-related chemicals to an acceptable level.
Representative concentration	An estimate of the concentration of a release-related chemical in a medium within a decision unit.
Residential indoor air action level	For a given chemical, ten times the IDEM published level for residential indoor air, which corresponds to a carcinogenic risk of 10^{-4} or a hazard quotient of ten, whichever results in a lower concentration.
Shallow soil gas	Soil gas from no more than five feet below ground surface.
Source area	A physical location where release-related chemicals are present in one phase at concentrations high enough to enable them to readily transfer to a different phase at concentrations that require a remedy.

Source facility	The building, land, operation, or enterprise, etc. from which release-related chemicals were released into the environment.
Source mass	The mass of release-related chemicals in a source area.
Source point	The physical location where release-related chemicals first entered the environment.
Unconditional closure	A closure that does not require an ongoing remedy.
Unconditional remediation objective	A remediation objective that permits unrestricted use of a decision unit. Examples include IDEM's published levels for residential exposure scenarios, naturally occurring background levels, project-specific residential levels, or in some cases ecological screening levels.
Volatile organic chemical	A chemical having a vapor pressure greater than one millimeter of mercury at standard conditions.

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